GEOGRAPHY

PHYSICAL

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HARMON · B · NIVER

Geography

Grade 8A
Mathematical and Physical

By
Harmon B. Niver

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PREFACE

The following brief treatise on the elements of mathematical and physical geography has been prepared to meet the requirements of elementary schools. Much of the material here given has already been taken up at intervals during the regular geographical course. Enough new matter has been added to provide for a term's work on these subjects. A number of astronomical facts have been given in the first chapter, not strictly related to geography but such as everyone ought to know. Chapters V and VI, dealing with the magnetism of the earth, the moon's phases, and eclipses, are also not defensible as geography, but are introduced as matters of general information. The remaining chapters of the book treat of the general features of the earth, of the forces at work in altering its surface, and of atmospheric and oceanic movements. The final chapters deal with the distribution of plant and animal life and with the races of man and their physical and social characteristics. It is believed that the book can be used as the basis for a half-year of profitable work at the close of the elementary school course.

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GEOGRAPHY MATHEMATICAL AND PHYSICAL

CHAPTER I

THE EARTH AS A PLANET

Fixed Stars and Planets. We have learned that the earth is a great round ball composed of land, water, and air, and that it is traveling rapidly onward in its never-ending journey around the sun. But perhaps we have never thought of the earth as having any likeness to the stars which we see in the skies on a clear night. It is hard to believe that it is really one of that company of glittering lights that flash and twinkle in the far off depths of space.

If we observe the stars carefully night after night, we shall become familiar with the **constellations,** or star-groups, which were observed and named by astronomers thousands of years ago. Most of us can recognize the **Great Bear,** or Dipper, the v-shaped **Hyades,** and the **Pleiades,** or Seven Sisters, above them. **Orion** with the three stars in his belt, the **Twins, Sirius,** the Dog-Star, the brightest in the sky, **Hercules, Polaris,** or the **North Star,** are other constellations and stars with which we should become acquainted. With the eye alone we can

see only a few thousand stars; but when a telescope is used, millions of others are brought into view.

Nearly all of the stars that we can see are **fixed stars.** They occupy to-day nearly the same positions in the skies as when man first beheld them. Other stars change their positions from night to night, until after a certain time they return to the positions where they were first observed. There are seven principal stars of this class which we may observe from the earth. They are called **planets,** a word meaning *wanderers*. The earth also is a planet, and if we could see it from a great distance, as we see the other planets, it would appear to us like one of them.

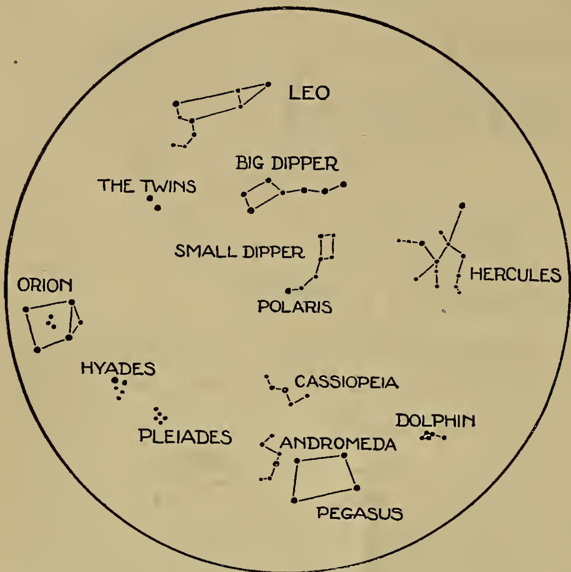


Fig. 1. Some of the constellations surrounding the North star.

The planets have been named after the Greek and Roman gods. Nearest the sun is **Mercury,** named for the messenger of the gods because of his swiftness. Next is **Venus,** the brightest of the planets, named after the goddess of beauty. Beyond the earth is **Mars,** which received the name of the war-god on account of its red color. Next is **Jupiter,** the largest planet, and hence named after the king of the gods. Most distant from the sun are **Saturn, Uranus,** and **Neptune.** Between Mars and Jupiter are several hundred smaller planets called **asteroids.** These and Neptune cannot be seen without a telescope.

The planets **revolve** about the sun, but at different distances from it. The nearer a planet is to the sun, the faster it moves. Our earth makes one complete revolution in 365¼ days. This period we call a **year.** Mercury, the planet nearest the sun, makes the journey in 87 days. Mercury's *year*, therefore, is only about one fourth as long as ours. Neptune, the most distant planet, is 30 times as far away from the sun as the earth. He travels only one sixth as fast as the earth, and requires 165 years as long as ours to make one journey around the sun.

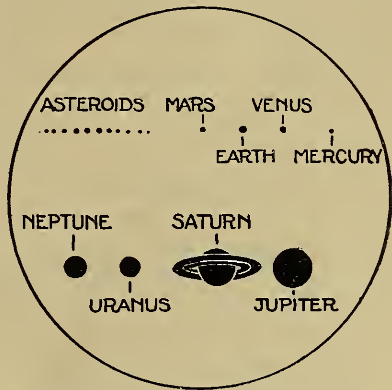


Fig. 2. Showing the relative sizes of the planets.

The following table shows the chief numerical facts about the eight greater planets approximately correct in round numbers.

Name	Diameter in miles	Average distance from the sun in millions of miles	Time of Revolution in days	Velocity in miles per second
Mercury	3,000	36	87	29
Venus	7,700	67	225	22
Earth	7,918	92	365	18
Mars	4,200	141	687	15
Jupiter	86,000	483	4,333	8
Saturn	73,000	886	10,759	6
Uranus	32,000	1,800	30,687	4
Neptune	35,000	2,800	60,181	3

The laws governing the motions of the planets were discovered by Johann Kepler, a German astronomer, in the early part of the 17th century. The first law is stated as follows: The orbit of each planet is an ellipse with the sun as one of its foci.

The method of drawing an ellipse is shown in Fig. 3. A loop of cord is passed around two pins driven into a piece of cardboard. The point of a pencil is then inserted in the loop, and, keeping the string stretched taut, the ellipse is described about the pins in the manner indicated. The points marked by the pins are the *foci*. If the distance between the pins be made less, or if the cord be lengthened, the form of the ellipse will more nearly approach a circle and the major axis and the minor axis (Fig. 4.) will be more nearly equal. The deviation of an ellipse from the circular form is called its "eccentricity" and depends upon the distance between the foci.

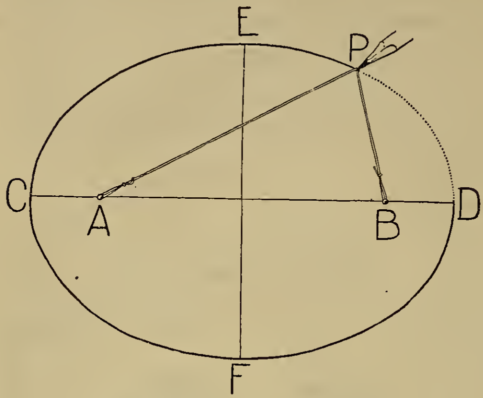


Fig. 3. Method of drawing an ellipse. A and B are the foci, CD the major axis, and EF the minor axis.

The orbits of the planets are nearly circular, as in Fig. 4. A planet when crossing the major axis at one of its extremities is at its greatest distance from the sun. This position is called its **aphelion**; when crossing the major axis at its other extremity it is in **perihelion**; that is, the position nearest the sun. The other laws of planetary motion are too difficult to be considered here.

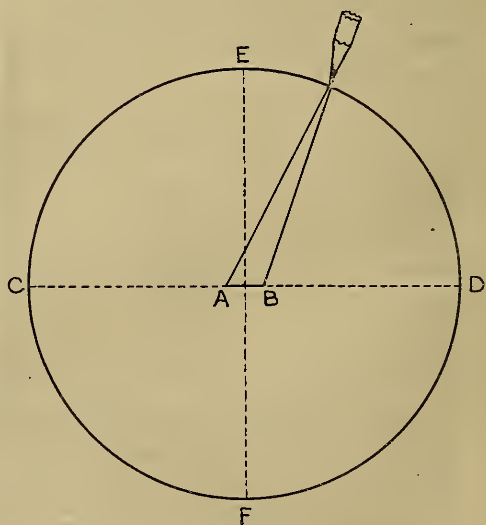


Fig. 4. An ellipse with very slight eccentricity resembling the orbits of the planets.

Moons. All the planets, except Mercury and Venus, have bodies revolving about them called **moons,** or satellites. We have all seen the **new moon** as a slender crescent in the west just after sunset. If we observe it for several nights at the same hour, we may notice that it is farther and farther above the horizon and that it appears to have moved toward the east. At the end of two weeks we may see it just after sunset as the **full moon,** near the eastern horizon; it has now moved all the way across the sky. Two weeks later it appears again in the west, having revolved entirely about the earth from west to east. All the moons revolve about their planets, and all the planets revolve about the sun in the same direction. With a telescope, or even with a good field-glass, we may watch the moons of **Jupiter** revolving about that planet. We may also watch the revolution of the planets about the sun, only these observations must be far more exact.

Comets and **Meteors** are strange, fiery bodies that occasionally appear in the heavens, and pass out of sight as mysteriously as they come. The comets circle about the sun, and then dart away on some unknown path into distant parts of the universe, sometimes reappearing after many years.

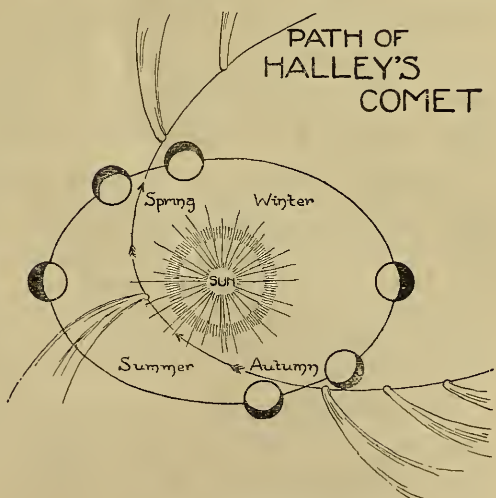


Fig. 5. A part of the path of Halley's comet, showing its progress around the sun, and its distance from the earth at different times.

Meteors, or "shooting" stars, flash suddenly through the earth's atmosphere, some turning to vapor and others falling upon its surface.

One of the most remarkable comets whose period of revolution about the sun is known is that named after **Edmund Halley,** who predicted its appearance in 1759. This comet enters the solar system and passes about the sun every seventy-five years. It was first seen before the Christian Era. It was noticed again in 684, 1066, 1456, 1682, 1759, and 1835. Its last appearance was in 1910. A portion of its path about the sun is shown in Fig. 5.

The Solar System is a name given to the sun and all the planets with their moons that revolve about it. The **sun** is the center of the solar system. It is thought to be a white hot mass of matter enveloped in burning vapors. Great flames leap from its **surface** to a height of over 200,000 miles, a distance nearly as great as that from the earth to the moon. The **diameter** of the sun is 866,500 miles, or about one hundred times that of the earth. Its **volume** is 1,300,000 times as great as that of the earth and its average distance from the earth is about 93,000,000 miles. The sun supplies the earth with the **light** and **heat** necessary to support plant and animal life.

The sun is really one of the fixed stars and the one nearest to us. Like the planets, it rotates about its axis. By means of the dark spots which sometimes appear upon its surface, its period of rotation has been found to be about 25 days. The amount of heat given out by the sun is so great as to be beyond computation. The earth alone receives enough heat in one year to melt a layer of ice 137 feet thick and covering its entire surface, yet the amount of heat received by the earth is only $\frac{1}{2,200,000,000}$ part of the total heat given out by the sun.

The **revolution** of the planets about the sun was discovered about four centuries ago by a German astronomer named **Copernicus.** He showed also that day and night are caused by the rotation of the planets upon their axes. The sun rotates on its axis like a planet, and with all its

attending planets and their moons is moving slowly through space. The fixed stars are fiery suns like our own. Perhaps they, too, are centers of systems of planets; but they are so far away that even with our largest telescopes we can find out little about them.

The Nebular Theory. It is thought that the sun and all the planets were once one great mass of fiery vapor, filling all the space between the sun and the farthest planet. We do not know where this cloudy mass came from. But after a time it began to cool, and as it grew smaller, began to rotate slowly about its axis, just as the earth does now. This motion caused it to bulge out at the equator and flatten at the poles. The motion at the equator became so rapid that a number of **rings** of vaporous matter

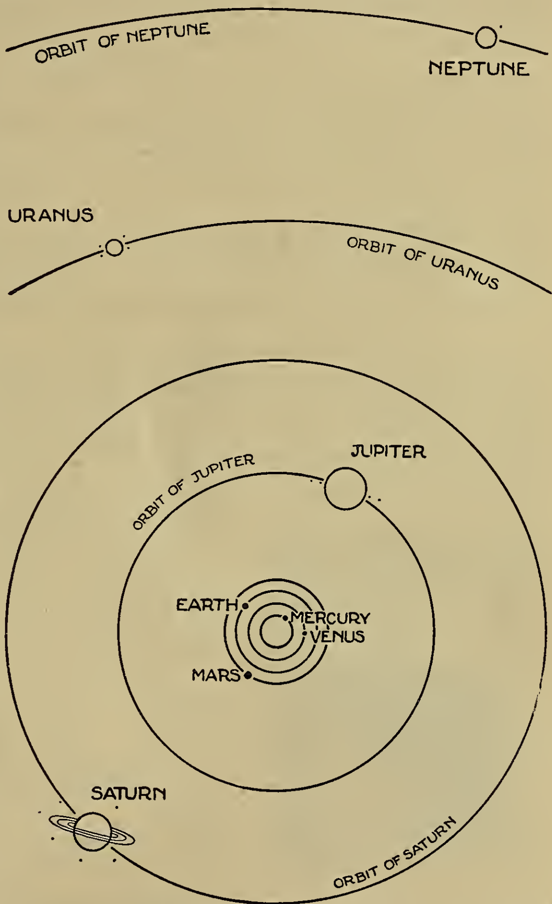


Fig. 6. The planets and their orbits, showing relative distances from the sun.

were thrown off. These rings in some way gradually became spheres and continued to revolve as planets about the central mass, or sun. Some of the planets themselves threw off rings which formed into moons.

The **planets** were once white hot, as the sun is now; but as they cooled at the surface, a hard crust formed, which grew thicker and thicker as the cooling continued. But how did this crust, which must have been smooth at first, become so rough and irregular? When melted rock cools it becomes about one seventh of its volume smaller; accordingly, as the hot rock within the crust went on cooling, it kept shrinking, and contracting. The crust, on account of its weight, pressed toward the center, and crumpled here and there in broad folds, like a garment that does not fit, or like a carpet that is too large for a floor.

The earth has been compared to an apple that has been baked. The heat makes the apple expand until the skin is almost bursting, but when the apple cools it shrinks until the skin becomes too large and lies in folds, or wrinkles. The **upward** folds formed by the cooling of the earth grew into the continents, while into the **downward** folds poured the waters that had been condensed from the clouds of steam surrounding the earth.

Fig. 7. Photograph of a baked apple.

There are several reasons for believing this theory. First, the **motions** of the sun, the planets, and their moons are all in the same direction. Second, the planet Saturn has still two **rings** circling about it. Again, the planet Jupiter is still so hot that its atmosphere is filled with clouds of steam. That the interior of our earth is highly heated is shown by hot springs and volcanoes which break through its surface. That the moon was once in a heated condition is evident from the dead volcanoes still visible upon it. We believe that the sun is still cooling and contracting; and perhaps it may yet throw off rings of matter to be formed into planets. It is

thought, also, that the earth, the planets, and the sun itself will some day grow cold like our moon, and that all life upon the earth will cease.

Gravitation. The members of the solar system as well as all the distant stars are held in their places by a force called gravitation; their motions also and the paths they follow are effects of the same force.

The law of gravitation as stated by Sir Isaac Newton, who discovered it, is as follows:

Every particle of matter in the universe attracts every other particle of matter, with a force which varies directly as the masses of the particles, and inversely as the square of the distance between them.

Gravitation is thus a form of **attraction** that tends to draw bodies of matter together. We do not understand the cause of it any more than we understand why a magnet attracts a piece of steel or iron. From the first part of the law it follows that if the amount of matter that two bodies contain should be doubled, the attractive force between them would be doubled. The second part of the law means that if the bodies should be twice as far apart, the attraction would be only one fourth as great; if the distance be three times as great then the attraction between them will be only one ninth as great. On the contrary, if the distance be divided by two, the attraction will be multiplied by four, etc. It is the force of gravitation which causes bodies to fall to the earth and which gives them **weight.** It is said that Newton's attention was first drawn to this subject by seeing an apple fall to the earth.

The onward motion of the planets causes a force, which tends to draw them away from the sun. This force is known as **inertia,** or centrifugal force. But the attraction between a planet and the sun (gravitation) is exactly equal

to the centrifugal force, and thus the planets are held in their courses.

A familiar illustration of the two forces named above is furnished by tying a string to a body and whirling it about in a circle. The tendency of the body to fly off in a straight line is the force of inertia, while the pull on the string may represent gravitation. These two forces are always equal. It may be added that if the speed of the body be increased the pull on the string will be correspondingly greater, and *vice versa.* This illustrates why the planets nearer the sun revolve more swiftly than those that are more remote.

REVIEW. 1. Describe some of the leading constellations. 2. Which one is useful in determining direction? 3. How may we distinguish planets and fixed stars? 4. Name the eight principal planets. 5. How is the motion of the planet affected by its distance from the sun? 6. Compare the year of Mercury with that of the earth. Compare also the year of Neptune. 7. What is the first law of planetary motion? 8. Describe the method of drawing an ellipse. 9. What is meant by aphelion and perihelion? 10. Which of the planets have moons? 11. Describe the changes in the appearance of the moon. 12. Comets and meteors. 13. What is meant by the Solar System? 14. Describe the sun and the amount of heat that it gives out. 15. Who was Copernicus? 16. Write a paragraph about the Nebular Theory. 17. State the law of gravitation. 18. What is meant by inertia?

CHAPTER II

FORM AND SIZE OF THE EARTH

The **shape** of the **earth** as well as that of the other planets and heavenly bodies is **spherical** or nearly so. This fact is easily established in the case of the other planets by direct observation; but it is not so easy to prove the shape of the earth, because so little of it can be seen at one time. By scientific methods, however a number of **proofs** have been accumulated, which show conclusively that the earth is spherical. The first of these that we shall mention was observed by travelers more than 2,000 years ago. To one who travels north or south, new **stars** are constantly coming into view, while the stars behind disappear below the horizon. To an observer at the equator, the North star appears to be on the horizon. But as one travels north it gradually rises, until on reaching the pole it would appear directly overhead.

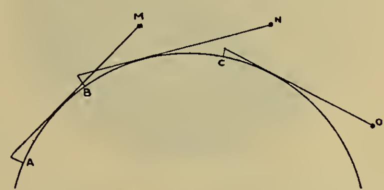


Fig. 8. In traveling from A toward B and C new stars appear to rise at N and O.

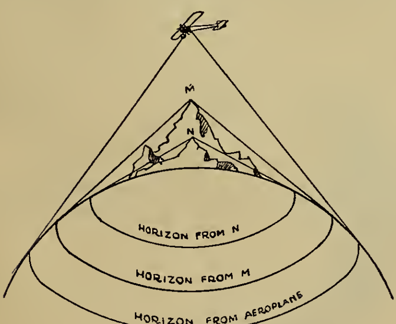


Fig. 9. The horizon seen from different elevations.

The well-known fact also that the sun rises earlier at places east of us and later at places west of us shows that

the surface of the earth is curved; for if it were flat the sun would rise and set at the same time for all places on the earth. There would also be no apparent rising and setting of the stars to a traveler going either north or south. Another proof is the shape of the **earth's shadow** as seen upon the moon at the time of an eclipse of the moon. This shadow is always circular, no matter what the position of the earth may be, and only a sphere always casts a circular shadow. Among the more familiar proofs of the earth's spherical shape is the circular appearance of the horizon when viewed from a great elevation. When ships are coming into port or sailing away, the tops of the masts are the first seen and the last to fade out of sight; whereas, if the surface of the earth were flat, the hull, being the most conspicuous part of a ship,

Fig. 10. The earth's shadow upon the moon.

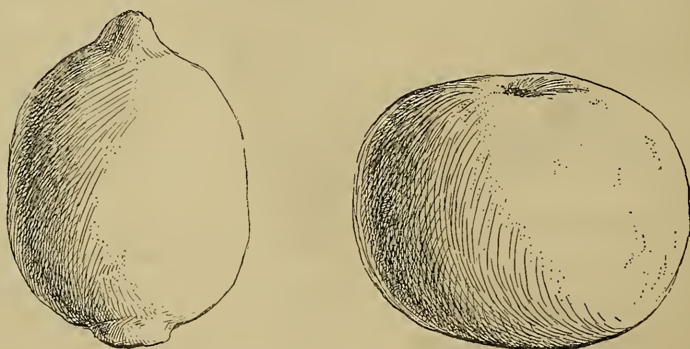


Fig. 11. An orange and lemon, illustrating spheroidal forms.

would be seen first. The circumnavigation of the earth is another familiar proof of its form. This, however, is not conclusive, as it must always be accomplished in an east and west direction; which would be possible if the earth were a cylinder. Finally, from analogy with the other members of the solar system, we might reasonably conclude that the earth is spherical.

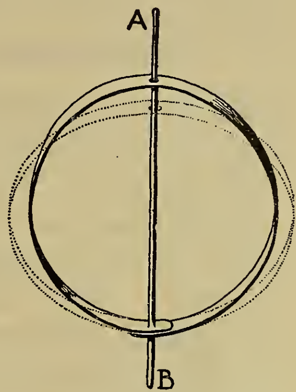


Fig. 12. Illustrating the effect of rotation on a plastic body.

The **form** and **size** of the earth have been accurately determined by scientific methods. The **polar diameter** has been found to be 7,900 miles, and the **equatorial diameter** 26 miles greater. The average **circumference** has been found to be 24,860 miles, and the circumference at the equator 24,900 miles. The earth therefore is not a perfect sphere, but is flattened at the poles. In exact terms, it is an **oblate spheroid.** The term applied to a sphere that has its polar diameter greatest is **prolate spheroid.** These two modifications of the spherical form are illustrated by an orange and a lemon as in Fig. 11.

The spheroidal form of the earth is supposed to have been caused by rotation when its was in a plastic condition. To illustrate the effect of rotation on a plastic body, take a strip of tin plate about two feet long and an inch wide; punch a hole in each end and also one in the middle. Bend the strip into a hoop and pass a wire through the holes and solder the two ends to the wire. Spin the metal hoop by rotating the wire between the fingers and note the effect indicated by the dotted lines in Fig. 12.

REVIEW. 1. State three proofs of the spherical shape of the earth. 2. What is the difference between the polar diameter and the equatorial diameter? Define oblate spheroid; prolate spheroid. 3. Illustrate the effect of rotation on a plastic body.

CHAPTER III

THE EARTH'S MOTIONS AND THEIR EFFECTS

Rotation and Revolution. These two motions of the earth may be illustrated by a spinning top which is moving about a center. If the axis of the top always points in the same direction and is inclined as the earth's axis is inclined, it will correctly represent the position and motions of the earth. The motion which the top would have if it remained in the same position is called **rotation,** while its onward motion around a center is called **revolution.** If the earth had no motion of rotation all places on its surface would have six months of daylight and six months of darkness during the time of one revolution. Again, if the earth remained always in one position and did not revolve about the sun, there would be no change of seasons. In this case, owing to the inclination of the earth's axis, the south frigid zone would have perpetual night if the position of the earth were at aphelion. If its position were at perihelion the north frigid zone would have perpetual night. If the position of the earth were at either equinox, or if the axis were perpendicular to the plane of the earth's orbit, all places on its surface would have days and nights of equal length throughout the year.

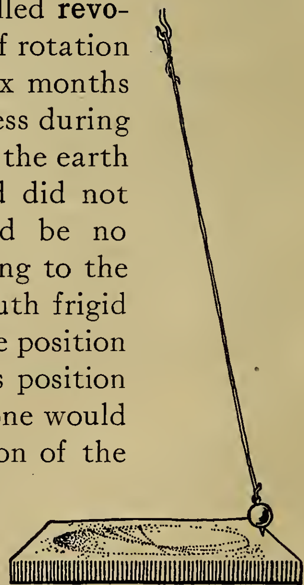


Fig. 13. Foucault's experiment, proving the rotation of the earth by means of a vibrating pendulum.

The time required by the earth to make one rotation is a **day** of twenty four hours. An object at the equator, therefore, is moving at the rate of about one thousand miles per hour, while the velocity of the earth in its motion of revolution is, as we have seen, slightly greater than this.

An interesting proof of the rotation of the earth is furnished by Foucault's experiment. He suspended a heavy pendulum from the dome in the cathedral of Notre Dame. Underneath it was placed a vessel containing sand. The pendulum was provided with a projecting tip at its lower end, as shown in Fig. 13. Such a long, heavy pendulum when set in motion will continue to vibrate for many hours in the same direction. As the earth rotates beneath it, the tip makes lines across the bed of sand, which extend through a complete circumference every twenty-four hours.

Direction on the earth's surface is determined by the direction of the axis and by the motion of rotation. The extremities of the axis are the north and south points, while the direction of rotation is called **east.** The **north** point may be found by observing the Polar star, or by means of the compass. The direction opposite to east is **west.** In the northern hemisphere the **south** point may be located by observing the position of the sun at noon.

Direction may also be determined by means of an ordinary watch. If the watch be held so that the hour hand points toward the sun the south point will be half way between this line and the twelve o'clock mark on the watch.

The Revolution of the Earth around the sun takes place in a trifle less than 365¼ days. Its orbit, or path, is an **ellipse,** but very nearly circular. The circumference of the orbit is 584,600,000 miles. The velocity, or rate of motion, as above stated is therefore about 18 miles a second. As the sun is located at one of the foci, its distance from the earth varies from 91,500,000 miles in December to 94,500,000 in June.

The Change of Seasons is not due to the *varying distance* of the sun from the earth, but to the direction in which the sun's rays fall upon it and to the varying length of the day. We have observed that the sun is low in the sky in

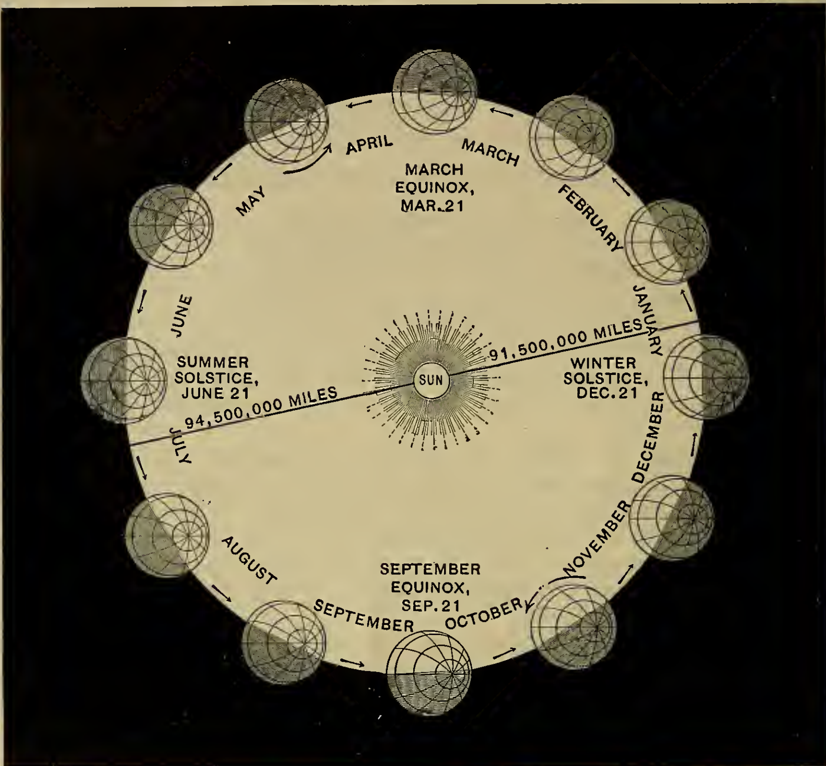


Fig. 14. The earth in its orbit, showing its position each month.

winter and high in summer; and also that the higher it is the longer its daily path in the sky. We may say that the length of the day varies according to the height of the sun.

In Fig. 15 the dotted curved lines represent the apparent path of the sun through the sky and the length of the day at the beginning of each season. On December 21st, winter begins and the sun is at its lowest position. This is the **winter solstice** (sun-stop). During the next three months it rises to the middle curve, when the days and nights are equal in length and the sun rises in the true east and sets in the true west This is the time of the **vernal equinox.** By June 21st, the **summer solstice,** the sun has reached the highest curve, and summer begins. After this date the sun returns to the **autumnal**

equinox on September 21st, and three months later, to the winter solstice. It will be noticed that the place of sunrise and that of sunset in the northern hemisphere is south of the true east and west during the winter, and north of these points during the summer.

The longer the day is, the more heat the earth receives. At night the earth gives up its heat. When the nights are shorter than the days, the earth receives more heat than it gives up. Hence the heat accumulates. This explains why the month of August may be warmer than June although the days are shorter. But the sun's rays are more direct in June than in August, and convey more heat to the earth, because they are spread over a smaller surface and also because less of their heat is absorbed by the atmosphere.

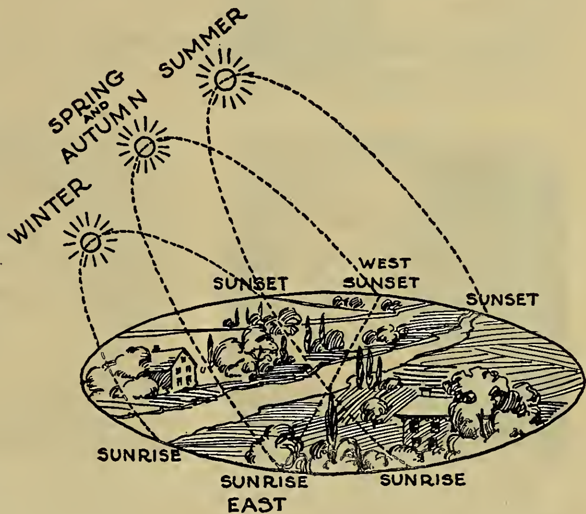


Fig. 15. The earth's daily path through the sky at different seasons. Notice the place of sunrise and sunset.

The Explanation of the Sun's Apparent Motion and of the changes in the seasons and in the length of the day is found in the **revolution** of the earth about the sun and the **inclination** of its axis to the plane of its orbit. The amount of the inclination is $23\frac{1}{2}°$. Since the axis always points in the same direction, it is plain that when the earth is at the position indicated by June 21,

in Fig. 17, the north pole of its axis will be turned toward the sun. At this time the sun will appear north of the equator and long days and summer will prevail in the northern hemisphere. On December 21, precisely the opposite conditions will prevail. In March and September the axis will be perpendicular to a straight line connecting the center of the sun with the center of the earth. Hence both northern and southern hemispheres will be equally lighted up, and the days and nights will be equal all over the earth.

Varying length of Day and Night. The length of the day in the northern hemisphere increases as the sun passes

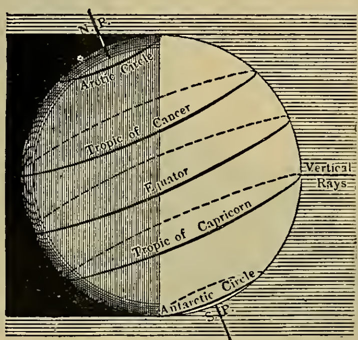


Fig. 16. Position of the earth at the time of the winter solstice.

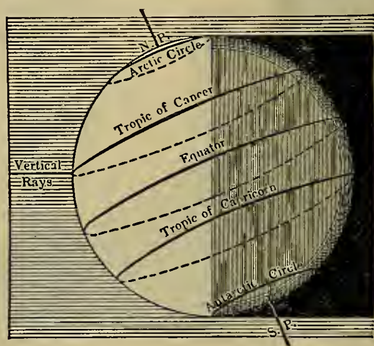


Fig. 17. Position of the earth at the summer solstice.

from the winter solstice to the summer solstice, and decreases in returning.

Let Fig. 16 represent the position of the earth at the winter solstice, December 21. The rays are vertical at the tropic of Capricorn and the whole south frigid zone is lighted up. What is true in the northern hemisphere? What do the circles show about the length of day and night? On March 21, the time of the vernal equinox, the sun's rays are vertical at the equator. What shows the equality in the length of the days and nights at this time? On June 21, the longest days are

found north of the equator and the shortest days are south of it. Which zones have summer? Which winter? The position of the axis would be precisely the same on September 21 as on March 21. Remembering this, how long would the day be at the north pole? At the equator? What can you say of the length of the days and nights between the equator and the poles at this time?

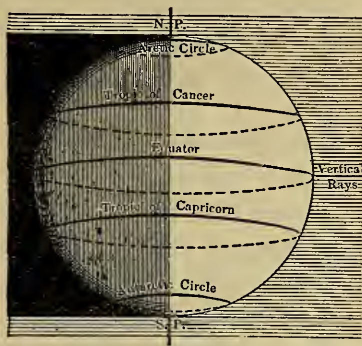


Fig. 18. The position of the earth at the time of the equinoxes.

The Earth and Man. Of all the planets, the earth is the one best fitted for human life as we know it. If it were too far from the sun the cold could not be endured; and if too near, the heat would be too great. The moderate inclination of the earth's axis allows an agreeable change of season and makes the larger part of the earth habitable. What would be the effect if the inclination were 50 degrees? What if there were no inclination of the axis?

REVIEW. 1. How does a top illustrate the rotation and revolution of the earth? 2. State the chief effects of each of these motions. 3. What would be the result if the earth did not rotate on its axis? What if it did not revolve about the sun? 4. Compare the velocity of the earth's motion of rotation with that of its revolution. 5. Describe the different methods of finding direction on the earth. 6. Why does the distance of the earth from the sun vary? 7. What causes the change of seasons? 8. Describe the position of the sun at the summer solstice; at the winter solstice; at the equinoxes. 9. At what circles is the sun vertical on each of these dates? 10. Why is the heating effect of the vertical rays of the sun greater than that of slanting rays? 11. Explain the cause of the sun's apparent motion in the sky. 12. What is the effect of the inclination of the earth's axis? 13. What points on the earth's surface have the longest day and the longest night? 14. Where are the days and nights equal throughout the year? 15. What can you say of the days and nights between the equator and the poles? 16. Why is the earth well fitted for the home of man?

CHAPTER IV

TIME AND DISTANCE ON THE EARTH

Location on a Sphere. Just as in our cities we locate places by means of streets and avenues, so on a sphere we have for this purpose **meridians** and **parallels.** Meridians are lines drawn on a sphere from pole to pole. Two meridians on opposite sides of the sphere make a **meridian circle.** The equator is drawn east and west midway between the poles. Circles drawn in the same direction as the equator are called parallels.

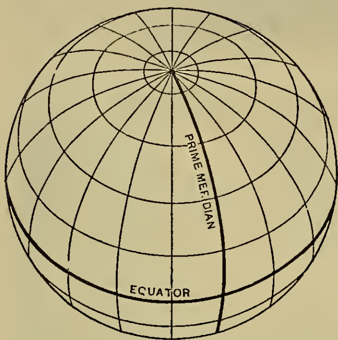


Fig. 19. Parallels and meridians, showing the meeting of meridians at the poles, and the varying length of parallels.

Latitude and Longitude. Distance north of the equator is called north latitude; south of the equator it is called south latitude. In reckoning longitude, the meridian passing through Greenwich, London, is taken as the standard meridian. Distance east of it is called east longitude, and west of it, west longitude. The location of a place on the earth's surface is given by naming the parallel and meridian that intersect at that point. Thus New York City is in longitude 74°, 0′, 3″ West, and in latitude 40°, 42′, 43″ north. The length of a degree of latitude at the equator is 68.7 miles; but owing to spheroidal shape of the earth (see page 13), it increases to 69.4 miles at the poles.

A degree of longitude at the equator is $\frac{1}{360}$ of that circle, which is equal to $69\frac{1}{6}$ miles. But as the distance between meridians decreases as we approach the poles, the

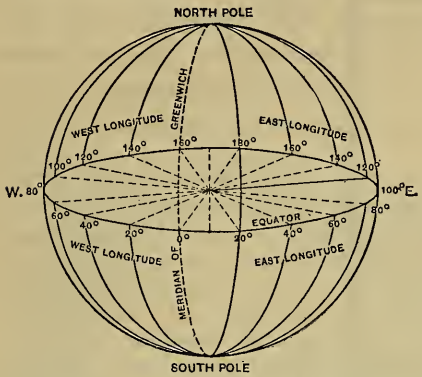


Fig. 20. The division of the equator into degrees of longitude.

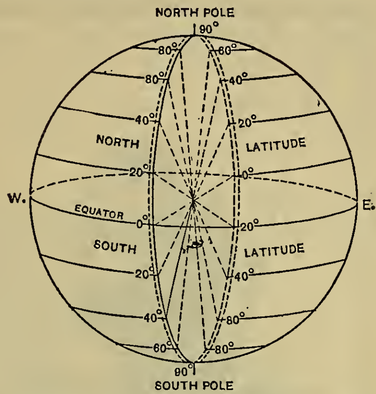


Fig. 21. A meridian circle divided into sections of twenty degrees latitude each.

length of a degree of longitude depends upon the latitude where it is measured. In the latitude of New York City it is 53 miles. At London, latitude 51½° N., it is about 45 miles. At 80° it is 12 miles, while at the poles, where all meridians meet, it is nothing.

LENGTH OF ONE DEGREE IN STATUTE MILES

In Latitude	0°,	1° Latitude	=68.70	miles,	1° Longitude	=69.17	miles.
"	10°,	"	=68.72	"	"	=68.12	"
"	20°,	"	=68.78	"	"	=65.02	"
"	30°,	"	=68.87	"	"	=59.95	"
"	40°,	"	=68.99	"	"	=53.06	"
"	50°,	"	=69.11	"	"	=44.55	"
"	60°,	"	=69.23	"	"	=34.67	"
"	70°,	"	=69.32	"	"	=23.72	"
"	80°,	"	=69.38	"	"	=12.05	"
"	90°,	"	=69.40	"	"	=00.00	"

How latitude and longitude are found. Latitude may be found by observing the height of the Polar star, or of

the sun, above the horizon. At the equator the Polar star appears on the horizon, and rises as the observer moves north. At the pole it is directly over head. Hence, the height of the star above the horizon will be equal to the latitude of the observer.

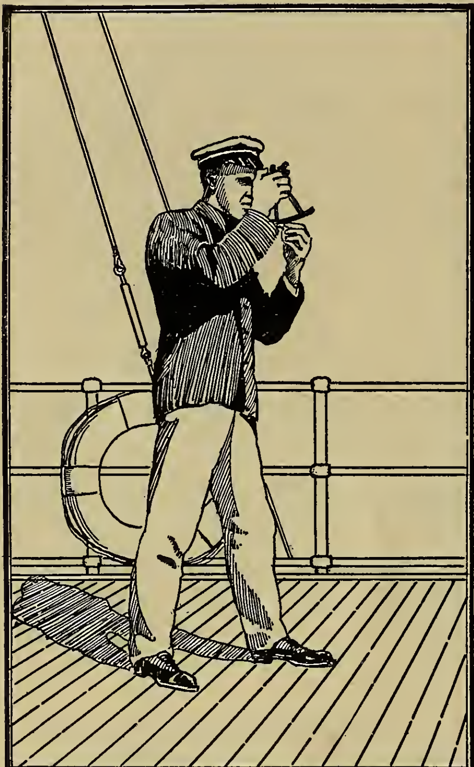


Fig. 22. Taking the altitude of the sun by means of a sextant.

The usual method of finding latitude at sea is by taking an observation of the sun at noon. By means of the sextant its apparent altitude above the horizon is determined in degrees, minutes, and seconds. To this *observed* altitude, corrections are made for refraction of the sun's rays, for the "dip" or depression of the horizon owing to the position of the observer, for parallax, for variation from Greenwich time, and for inaccuracies in the instrument. The semi-diameter of the sun is also subtracted from the observed altitude. This *corrected* altitude is then subtracted from 90° and the remainder is the sun's "zenith distance." The sun's distance north or south of the equator is known as **declination,** and is given in the *nautical almanac* for every day of the year at 12 o'clock noon, Greenwich time. If the observer is on the same side of the equator as the sun, he adds the declination of the sun to its zenith distance. This sum is the latitude of the observer. But if the observer is on the side of the equator opposite to the sun, his latitude will be the difference between the zenith distance and the declination. The "sextant" is an elaborate instrument requiring much practice to use it correctly.

Longitude at sea is found from its relation to time. Since a point on the earth rotates through 360° of longitude in 24 hours, it will pass through 15° in one hour, or 15′ in one minute. That is, time in hours, minutes, and seconds is $\frac{1}{15}$ of the equivalent longitude. Now suppose a ship wished to know its longitude at sea. It has on board a very accurate clock keeping Greenwich time. By observing when the sun crosses the meridian, the ship obtains

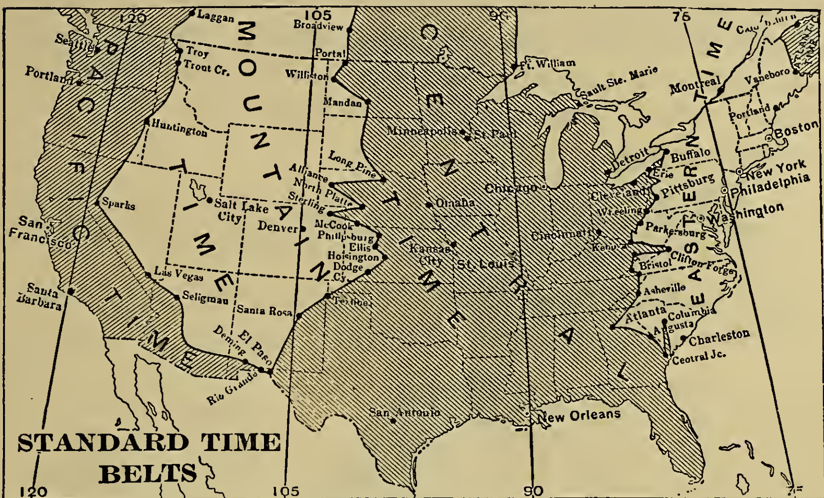


Fig. 23. Standard time belts.

its own local time. Suppose the Greenwich time is 9 o'clock and the ship's time 12 o'clock. This is a difference of three hours. Since one hour equals 15°, three hours equals 45°, and the ship will be in 45° east longitude. If the ship's time had been three hours earlier than the Greenwich time, it would be 45° west in longitude. Why?

Local and Standard Time. Time obtained from the sun at any place is called solar, or **local,** time. Since all places

in different longitudes must have different local time, the railroads of the United States and other countries have agreed upon systems of standard, or **railroad,** time. By this system it is arranged that the time shall change one hour for every 15° of longitude. By this method our country is divided into four time belts, so that one in traveling from the Atlantic coast to the Pacific coast will need to change a watch only four times. When traveling westward, a watch must be set back one hour on crossing each meridian; but when traveling eatward it is set ahead. On the meridians, solar and standard time will be the same. Half-way between them, there will be a difference of 7½° or 30 minutes of time.

As a matter of practice, railroads do not change their time exactly at the meridian, but at important centers that are nearest the meridian, as Buffalo, Pittsburgh, etc. (see map of the Time Belts).

International Date Line. The day begins at midnight and lasts until the next midnight. Since it is desirable that all nations should have the same number or date for each day, it has been agreed that the new day shall begin on the 180th meridian. At midnight, therefore, the new day begins and follows the sun westward around the world. When it reaches

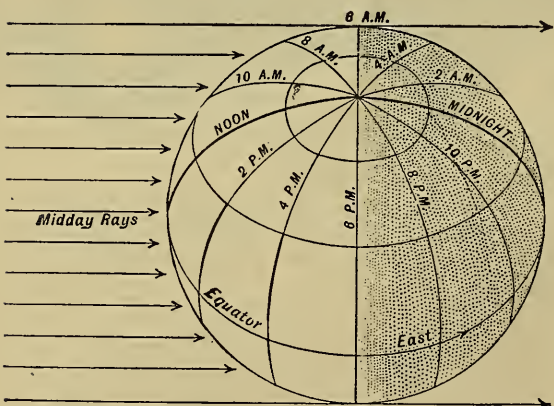


Fig. 24. Illustrating the relation of longitude and time. The meridians are drawn at intervals of thirty degrees. The time on each meridian is shown at the hour of noon on the prime meridian.

this "International Date Line," as it is called, a new day has begun. Thus when it is Sunday on the east of the line, it will be Monday on the west of it. If a ship should cross the line sailing east, it would have two Sundays; but when sailing west a day is dropped.

REVIEW. 1. How are places located on a sphere? 2. Define meridian, parallel, meridian circle. 3. Name the other leading circles drawn on the earth. 4. Great and small circles. 5. Define latitude, longitude, north and south latitude, east and west longitude. 6. Why do degrees of longitude vary in length? 7. Describe the method of finding the latitude of a place. 8. How does a sailor determine his longitude? 9. What is meant by local time? By standard time? 10. Describe the use of time belts. 11. What change does a traveler make in his time when going east? When going west? 12. International Date Line.

CHAPTER V

THE EARTH'S MAGNETISM

The Mariner's Compass. If a magnetized needle be suspended anywhere so that it may turn freely, it will point to two places on the earth's surface, which are called the north and the south **magnetic poles.** When such a needle is fastened to a card on which the points of the compass are written and mounted so that it may turn freely, we have an instrument that enables the sailor to find his way when the land and the stars cannot be seen.

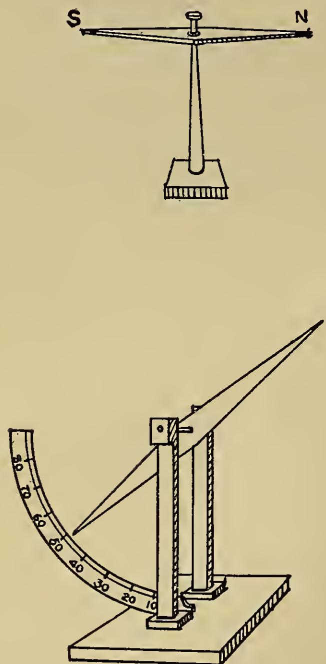


Fig. 25. A magnetic needle mounted horizontally. 2. A dipping needle.

If a needle horizontally suspended be moved along a bar magnet, one end of it will be drawn toward the north pole of the magnet, and the other end toward the south pole. This property of attracting iron and steel, whether exhibited by a magnet or by the earth, is called **magnetism.** The earth behaves exactly like the bar magnet, and hence has the property of magnetism.

The magnetic poles of the earth are not the true north and south poles. The north magnetic pole is in the northern part of North

America, near latitude 70° north and longitude 97° west. The south magnetic pole is near latitude 73° south and longitude 155° east.

Dipping Needle. The location of the magnetic poles is found by means of a dipping needle. When the needle points directly downward, the pole has been found. Since the magnetic poles are not coincident with the true north and south, the compass will vary from these directions. The amount of such magnetic variation is called **declination.**

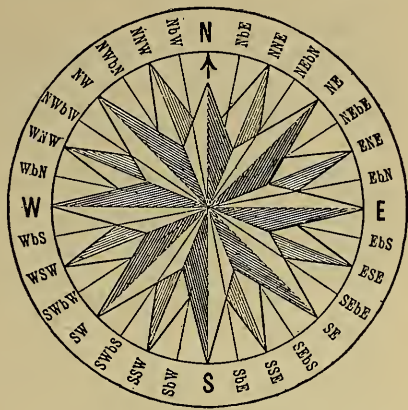


Fig. 26. A compass card. Naming all the points on the card is called "boxing the compass."

Declination. On the compass shown in Fig. 27 the declination is about 5°. The line along which the needle points is the **magnetic meridian.** When a magnetic meridian passes through the north and south geographical poles as well as the magnetic poles, it is called a "line of no variation." Along such lines the needle points to the true north and south. The sailor is provided with a chart which shows the exact amount of declination all over the earth.

The reason for the magnetism of the earth is not certainly known. It is thought that it may be caused by currents of electricity produced by the sun's rays as they pass

Fig. 27. A compass showing the declination of the needle.

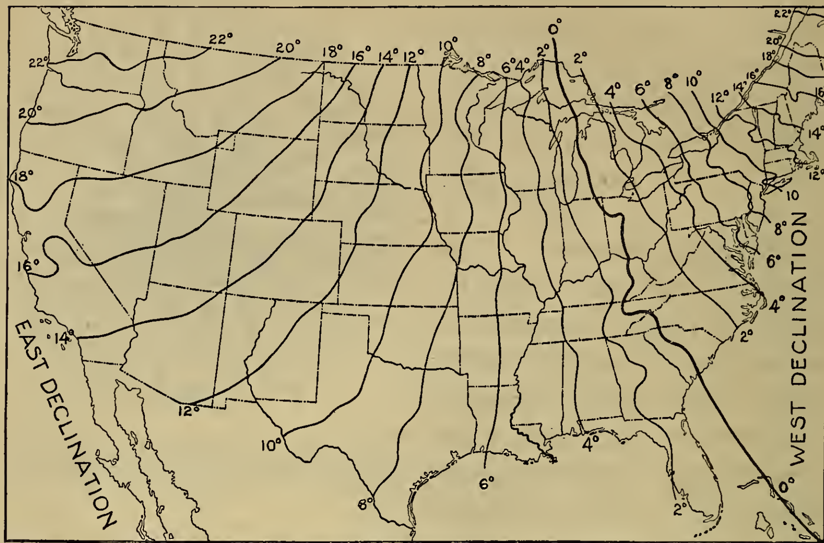


Fig. 28. Lines of magnetic declination in the United States.

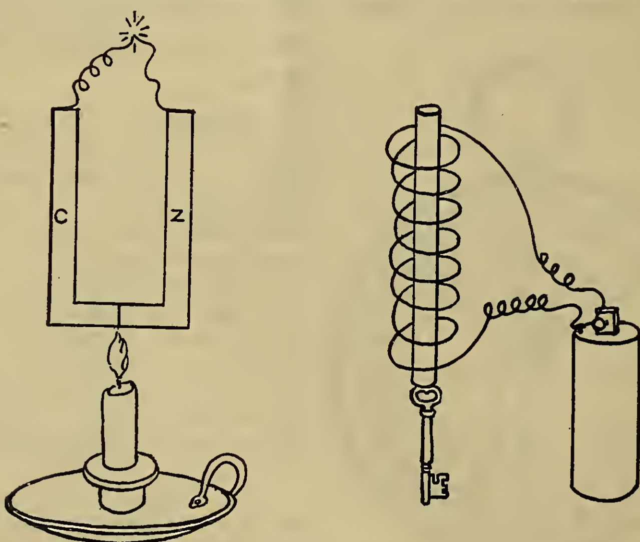


Fig. 29. The cut on the right shows how a bar of soft iron is made magnetic by passing an electric current around it. The cut on the left shows how an electric current may be caused by heating two pieces of metal joined together. These metals, owing to their nature, take up heat unequally, and hence the current is generated.

around the earth from the east to west. If a piece of soft iron be wound with a coil of wire, and an electric current sent through the wire, the iron will become magnetic; again, if two metals be soldered together and the point of the union be heated, a current of electricity will be established in the wires. These two experiments show how heat may produce electricity and how electricity may produce magnetism.

REVIEW. 1. Describe the construction of the mariner's compass. 2. To what places on the earth does the needle point? 3. What is the effect of moving a suspended needle along a bar magnet? 4. Define magnetism. 5. State the location of the magnetic poles of the earth. 6. In what places does the needle point to the true north and south? 7. What allowance must the mariner make at other places on the earth? 8. Explain the use of the dipping needle. 9. What is said about the cause of the earth's magnetism? 10. What experiments tend to prove this?

CHAPTER VI

PHASES OF THE MOON—ECLIPSES

Phases of the Moon. The sun and the stars are luminous (light-giving) bodies; but the planets and moons are opaque, and shine only because they reflect the light which they receive from luminous bodies.

Close all the windows of the school room but one, and place a globe having a polished surface where the light may strike upon it. If you walk around the globe, you may distinguish upon it phases of light similar to those of the moon.

Since the moon revolves about the earth, it will sometimes be on the same side of the earth as the sun. It may also be on the side of the earth opposite to the sun or may make any angle with the sun and earth. The amount of light that the moon reflects to us depends upon its position with reference to the sun and earth. The changes in the moon's appearance are called **phases** (Fig. 31). The earth's orbit and

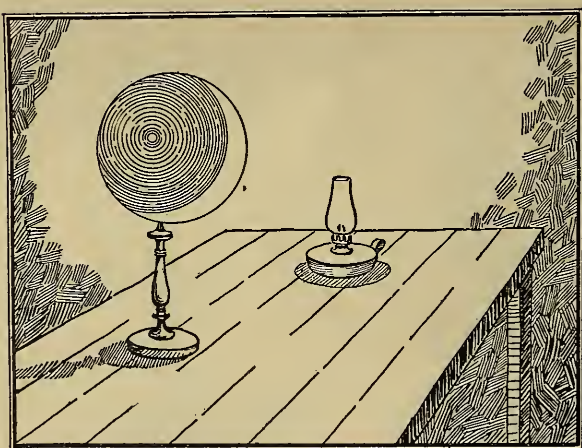


Fig. 30. Light reflected from a polished globe showing crescent. The observer is supposed to be in front of the picture at an angle with the lamp and the globe.

the moon's orbit are not in the same plane; hence the moon may be on the same side of the earth as the sun and

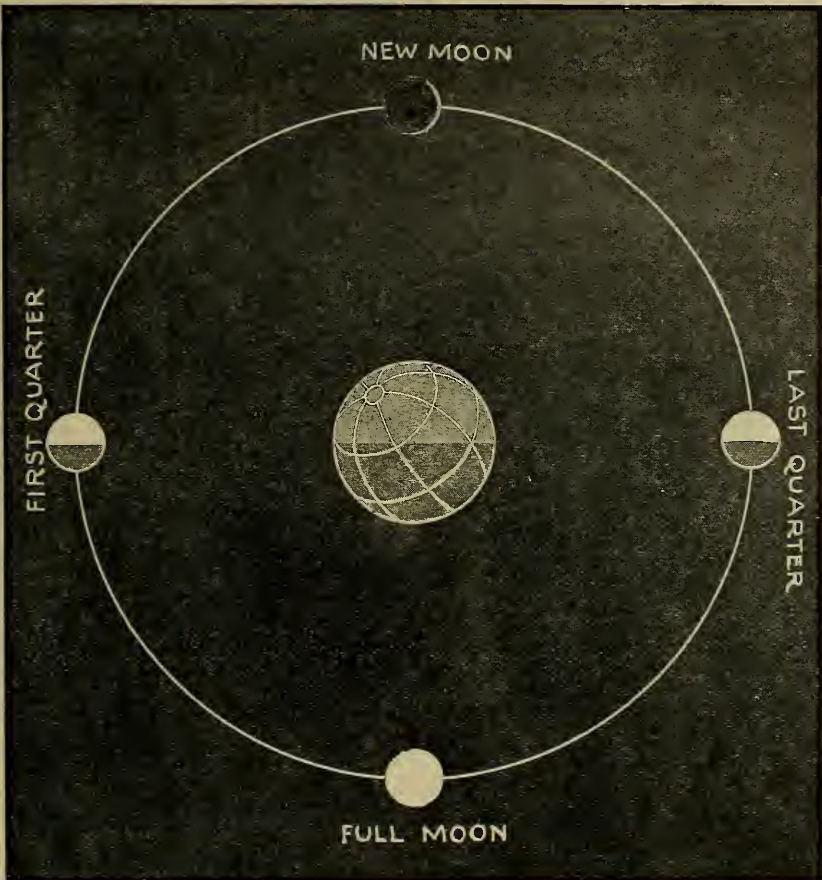


Fig. 31. The phases of the moon. The light comes from above the cut.

not be on the straight line connecting them. If in Fig. 32 you imagine the figure of the sun cut out and lifted perpendicularly about an inch above the page, you may see that the sun, moon, and earth will not be in the same straight

line. It will also be apparent that the moon will be unequally lighted up in its revolution about the earth.

Eclipse of the Moon. The earth, being an opaque body, casts a long conical shadow into space. As this shadow extends outward into space far beyond the path of the moon, it often happens that the moon passes through the shadow in its monthly journey around the earth. It is then dark, or "eclipsed." An eclipse occurs at or near the time of full moon. Only a part of the moon may be in the shadow. It is then a "partial" eclipse. If the entire surface is in the shadow, it is a "total" eclipse. The partially shaded region in the diagram darkens the moon slightly when it passes through, but it is not eclipsed until it enters the umbra, or region of total shadow.

An eclipse of the **sun** may occur when the moon comes between the sun and the earth. If you hold an object between your eye and the sun, the shadow of the object falls upon the eye and cuts off part of the light. If the object be moved closer to the eye, its shadow is larger and cuts off more light; if it be moved away from the eye, the shadow is smaller and cuts off less light. If it be moved far enough away, the shadow will not reach the eye and hence no light is cut off. The distance of the moon from the earth varies from about 222,000 to 253,000 miles.

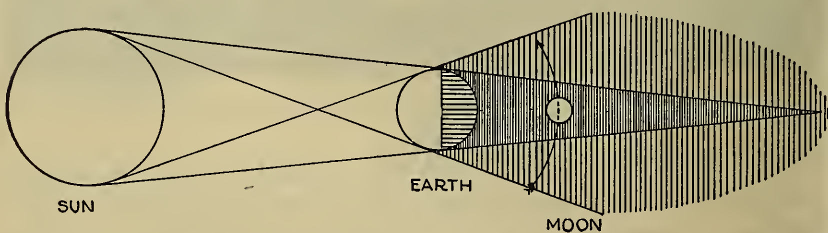


Fig. 32. The relative positions of the moon, earth, and sun, at time of total eclipse of the moon.

The length of the moon's shadow averages 232,000 miles. It is clear that the shadow will sometimes reach the earth, but oftener will fail to do so. When it does reach the earth, the people who live in the region where the shadow falls will see an eclipse of the sun.

The moon may entirely cover the sun and cause a total eclipse or it may pass as a black crescent across the sun's edge and thus cause a

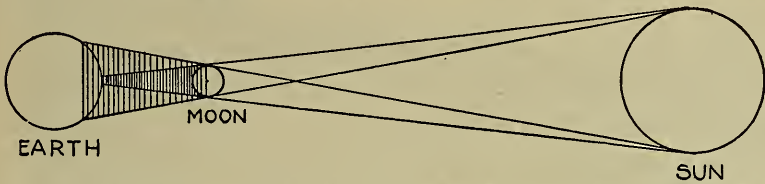


Fig. 33. Relative positions of the sun, moon, and earth during an eclipse of the sun.

partial eclipse; or it may pass across the center of the sun's disk at such a distance from the earth that a ring of light will be seen around the outer edge of the sun. This is called an "annular," or ringed eclipse.

REVIEW. 1. Luminous and opaque bodies. Illustrations of each class. Describe the motion of the moon. In which position does it send us the most light? When is it a "dark" moon? What is meant by new moon and full moon (page 31)? 2. What is the cause of an eclipse of the moon? Why can an eclipse occur only at or near the time of full moon? Total eclipse. Partial eclipse. What causes an eclipse of the sun? Why is the moon nearer the earth at certain periods than at other periods? Explain how a total eclipse is caused; a partial eclipse; an annular eclipse.

CHAPTER VII

GENERAL FEATURES OF THE EARTH

The Four Spheres. We may describe the earth as composed of four spheres having a common center. The inmost of these, called the **centrosphere,** is a great ball forming the interior of the earth, while the others are hollow spheres enclosing it like the coatings of an onion. The centrosphere is over a hundred times as great in bulk as all the other parts of the earth together. It seems to consist of hard rock which is intensely hot, and which is kept from melting only by the great pressure exerted upon it by the crust of the earth.

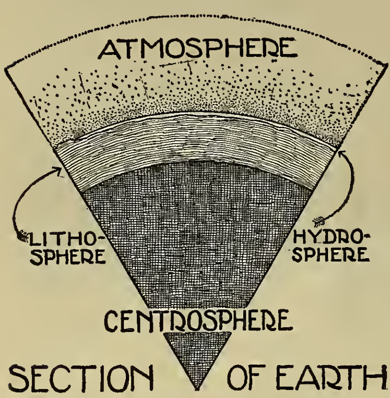


Fig. 34. A section of the earth, showing its structure.

The Lithosphere. Enclosing the central sphere is a crust composed of many varieties of rock and having a thickness varying from ten to twenty miles. This is usually called the earth's crust. The lithosphere is mainly composed of rock arranged in layers, or **stratified** rock. We may observe such rock where cuts have been made through hills for railroads. The walls of canyons carved out by rivers also show layers of rock of various colors.

The common kinds of stratified rock are sandstone, shale,

conglomerate, and limestone. **Sandstone** is made of grains of sand held together by some kind of cementing material. **Shale** consists of mud which has dried and hardened under pressure. Slate and bluestone are varieties of shale. These rocks are easily split into sheets of varying thick-

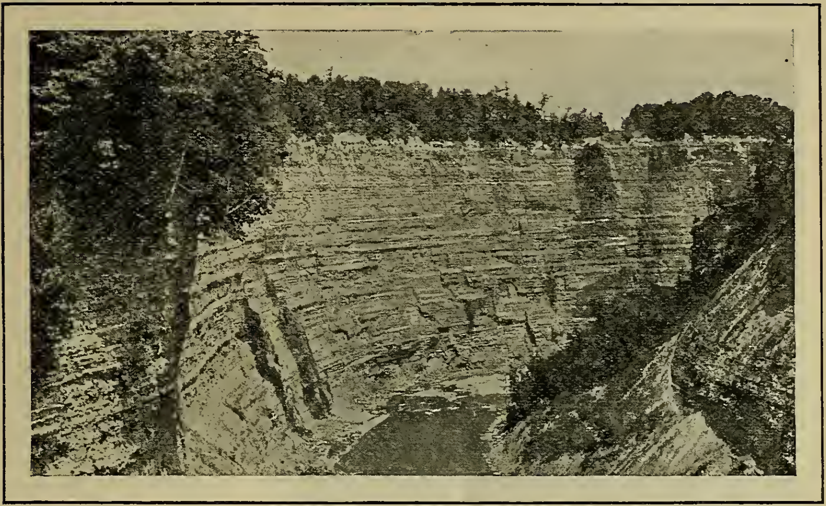


Fig. 35. Gorge of the Genesee river showing layer rock.

ness and are useful for sidewalks and for covering roofs. **Conglomerate** consists of gravel or coarse pebbles bound together in the same way as sandstone. Coarse conglomerate is sometimes called pudding-stone. **Limestone** is made of the shells of animals that once lived in sea water. These have been ground up by the actions of the waves and breakers along the shore and mixed with mud and sand. Afterwards they have been buried deep under the deposit brought down by streams, and by heat and pressure have been changed into firm rock.

History of Layer Rock. Nearly all the layer rock in

the world has been made of fragments of older rock which have been worn away from the land surface and carried down to the ocean by rivers. This material, in the form of mud or sand, has been spread out over the ocean bottom and afterwards hardened into rock. No matter where stratified rocks occur, whether in lowlands or on the highest mountains, they were at first laid down under water. It seems strange that rocks now a part of mountains thousands of feet in height were once at the bottom of some ocean. Yet we know this is true because the rocks contain the remains of plants and animals which can only live in salt water. By means of these remains, or **fossils,** we are able to learn much about the formation of rocks and about the succession of plants and animals that have existed upon the earth. It is evident that great changes must have taken place upon the earth in order to lift the bottom of the ocean up into hills and mountains.

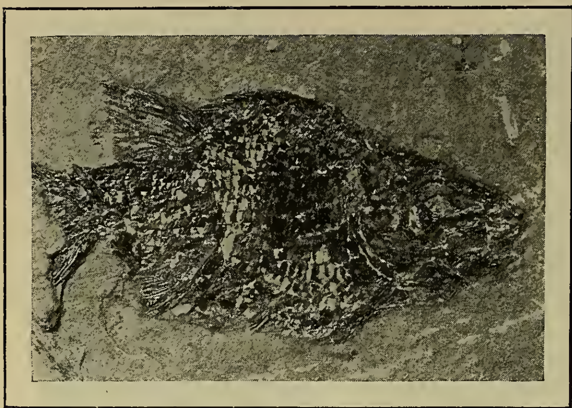


Fig. 36. A fossil fish taken from rocks near Boonton, New Jersey.

Stratified rock is seldom found in the form or position in which it was at first laid down. Much of it has been changed, not only in level, in appearance, and in texture, but it has been folded, twisted, crumpled, and carved by the forces of nature. Much of it after having been lifted up into hills and mountains has again been worn away by the action of the elements and carried back to the ocean or spread out along the lower courses of rivers to form alluvial plains and deltas.

Much of it has decayed to form the soil which composes the outer layer of the earth's crust and which supports innumerable forms of vegetation and the animals that depend on plants for food.

Crystalline rocks. Rock that has cooled after melting, or layer rock which has been changed by the action of heat so that little or no trace of the original formation remains, is called crystalline or **metamorphic** (changed) rock. Such rock is composed of crystals of various forms packed solidly together. Granite, marble, and gneiss are the common varieties of crystalline rock. Granite is crystallized sandstone or conglomerate. Marble is crystallized limestone. Gneiss and various forms of rock containing mica bear traces of the original layer formation. Rocks which have cooled after fusion are called **igneous** rocks. Lava and basalt are the usual varieties (Fig. 40). In the neighborhood of boiling springs and geysers, crystalline rocks are found which have resulted from the cooling of the hot water containing rock material in solution. All varieties

Fig. 37. View in a marble quarry, near Rutland, Vermont. Notice the regular structure of the layers.

of precious stones have crystallized from solution or have been formed through the action of intense heat.

Metamorphic rock is found everywhere underlying the layer rock and extends an unknown distance toward the center of the earth. Much of it, especially volcanic rock, is found at the surface spread out in layers or in ridges and mountains that have forced their way upward through pressure within the crust of the earth. Crystalline rocks are usually very hard and are well adapted for building purposes.

Soil. All rock, whether stratified or crystalline, when lifted to the surface and exposed to the action of the elements begins to decay (Fig. 38). The rapidity of decay depends upon the hardness of the rock exposed. Shales and sandstones decay most easily, but the harder crystalline rocks decay very slowly. After a time, therefore, the surface of the rock is overlayed by a layer of loose material which we call **mantle rock** or soil. The soil is of the greatest value to mankind, since it supports all the plant life of the earth, without which no animal life could exist. Soil is found everywhere on the land surface except on the steep sides and summits of hills and mountains. It varies in thickness from a few inches

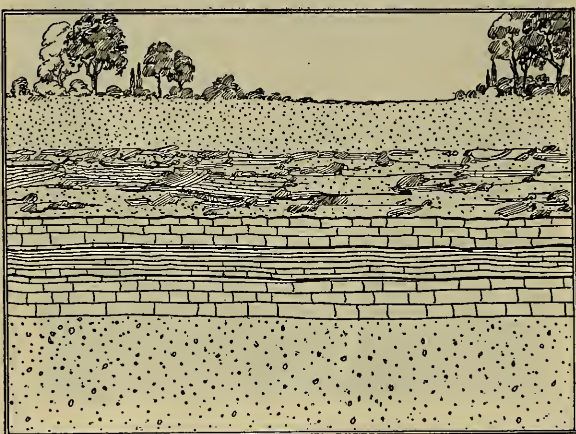


Fig. 38. Sectional view showing soil and rock layers. At the bottom of the cut is shown hard, crystalline rock. Overlying this is stratified rock. Next rock is shown in various stages of decay. Above the decayed rock is a layer of soil with vegetation growing above it.

in elevated regions to scores of feet in lowland plains. The common varieties of soil are **sand, clay,** and **gravel** and mixtures of these. Sand and clay together form **loam.** When loam contains decayed vegetable or animal matter it becomes fertile and suitable for the cultivation of plants. Decayed limestone or phosphate rock adds greatly to the fertility of the soil. Soil must be loose enough to allow air and moisture to enter it, and it requires a mixture of clay or an underlying stratum of waterproof rock, so that it may retain moisture for a considerable time. **Marl** and **peat** are varieties of soil used as fertilizers. Marl is a mixture of clay and lime formed under water from the remains of shellfish and the sediment of rivers. Peat is a black soil found in swamps, and is derived from decayed vegetable matter. When dried it is useful as fuel. The character of soil in general depends upon the kind of rock from which it was formed. Limestone and lava when decayed form the best bases of a fertile soil. The value of soil depends upon the proportion of plant food which it contains. Since all plants do not require the same kind of food it becomes an important part of scientific agriculture to raise plants on the soil best suited to them or to supply to the soil the food elements necessary to produce the crops desired.

Minerals. All soils and the rocks from which they come are composed of minerals. The word mineral is a term which applies to all substances that are not derived from plant or animal life. The atmosphere, the waters, and the great bulk of the earth belong to the mineral, or inorganic kingdom. The common varieties of minerals are **quartz, feldspar, mica, lime,** and **carbon.** These exist in many forms and combinations. The various **metals** and

ores are also among the common minerals. Sand is composed of minute grains of quartz, mica, and other minerals. Feldspar when decayed forms clay. Carbon comes from decayed plants, and lime from the shells and bones of

Fig. 39. A marl bed in New Jersey.

animals. Minerals when transparent, become **gems.** The diamond is pure crystallized carbon. The amethyst, opal, agate, onyx, and other gems consist of crystalline forms of silica or quartz.

Hydrosphere. The meeting place of the gaseous part of the earth with the solid and liquid parts is called its surface. We learn from the study of the surface of the earth that at some time in its history it consisted entirely of the waters of the ocean. But at the present time the **ocean** composes only three fourths of the surface, while the remaining fourth consists of the continents and islands. The

ocean surrounds the continents on every side and receives all the streams that flow from them. It is thus broken into several large divisions and many smaller ones which have received appropriate names. During past ages the ocean floors have sunk, while the continents have risen.

Fig. 40. Columns of volcanic rock near Orange, New Jersey.

The effect of this has been to quicken the action of streams and to increase the amount of sediment which they carry to the ocean. As a result of this the surface of the land has become very irregular while the ocean floors have been leveled by the deposit of sediment and by the accumulation of plant and animal remains which have sunk to the bottom.

The Continents. The parts of the earth which gradually rose above the waters have grown into the great masses of land which we call continents. Two of these masses begin at the north pole and extend southward. The larger

includes the grand divisions of Asia, Europe, and Africa, and the smaller, those of North America and South America. The third great land mass lies wholly southward of the equator, forming the continent of Australia. Another great land mass, which has been only partially explored, lies in the south frigid zone. It has received the name **Antarctica.** Partially enclosed by the great land masses are the four leading divisions of the ocean, the Atlantic, Pacific, Indian and Arctic.

Four of the continents are built on the basin model; that is, they are high near the borders and low in the interior. Asia and Africa, however, have high interior regions and low bordering plains of varying breadth. The highest mountains are found along the margins of the largest and deepest oceans, while the lowest mountains, which are also the oldest, border the smaller and shallower ocean, the Atlantic.

The Atmosphere. The solid and liquid parts of the earth are surrounded by the lighter, gaseous **atmosphere,** which extends for many miles outward from the surface. Though the atmosphere is the lightest part of the earth's substance, it presses down upon the surface with considerable force and fills all the cavities in the rocks and soil. It finds its way down to the roots of plants and helps their growth. The

Fig. 41

Fig. 41. Cross sections of North America and South America, showing basin-like structure. Notice that the highest mountains are on the western border, and that the low mountains border the Atlantic ocean on the east.

oxygen of the air is necessary to all animal life. It is taken up by the waters, and even the deepest parts of rivers, lakes, and the oceans contain enough of it to keep alive the fish and other creatures that live there.

The origin of the continents may be explained by referring to the nebular theory. This theory tells us that after the earth's crust was formed, the interior continued to cool and contract until it became smaller than the crust. The latter was therefore drawn toward the center of the earth by its own weight, and being too large to fit the shrinking interior, it rose up here and there in broad folds like a garment that is too large for the body, or a carpet which is too large for a floor.

REVIEW. 1. Describe the four spheres that compose the earth. Which is the greater? 2. What is meant by stratified rock? 3. Name the common varieties and tell of what each is composed. 4. Explain how stratified rock has been formed. 5. What do we learn from fossils? 6. What is crystalline rock? 7. Name three varieties. 8. Where is crystalline rock found? 9. For what is it useful? 10. What is the origin of soil? 11. Describe the common varieties. 12. What is said of its thickness? 13. Name the leading minerals. 14 What is meant by the mineral world? 15. What are gems? 16. Describe the ocean. 17. Why is it supposed that it once covered the entire earth? 18. How does the surface of the land compare with the ocean floors? 19. How is the origin of the continents explained? 20. Describe the atmosphere. 21. Why is it farther from the center of the earth than the other "spheres?"

CHAPTER VIII

MOUNTAINS AND PLATEAUS

Occurrence and Formation. Any elevation of land above a moderate height is called a mountain. The mountains of the world are usually found in long rows, or ranges. A number of ranges when grouped together form a mountain chain or **system.** Mountain ranges and systems vary greatly in breadth and elevation. They consist usually of a vast mass which has been raised above the general level of the country, from the summit of which rise peaks more or less rugged, according to the resisting nature of their materials and to the length of time that they have been acted upon by the elements.

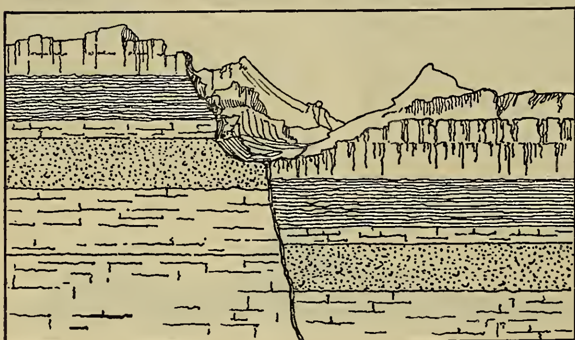


Fig. 42. Faulted strata. The center of the cut shows a fracture on the right of which the rock layers have sunk so that the strata on one side of the fracture do not coincide with those on the other side.

On plains the rock layers are usually found in a horizontal position, but in mountain ranges they are bent, folded, crumpled, and broken as though they had been raised violently upward or forced together by enormous lateral pressure. If a number of sheets of loose paper be pressed

together from the ends, the folds which result may be compared with the folds of strata found among mountains. Sometimes the strata are broken, and the rocks on one side of the fracture are lifted far above the corresponding rocks on the other side, producing a **fault.**

The forces which have produced the phenomena just described have been alluded to on page 44. The chief cause, however, of the rugged nature of mountain regions, as we see them to-day, is found in the agencies of erosion

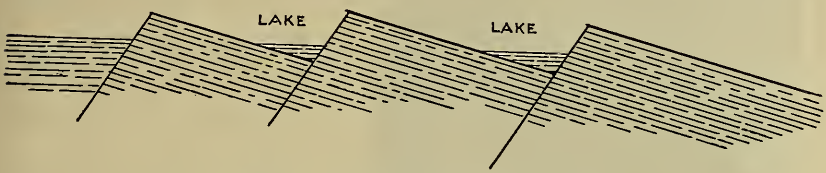


Fig. 43. Block structure of mountains.

and in the fact that the rocks vary greatly in hardness. As the softer parts are worn away by the elements, the harder rocks are left in jagged peaks and serrated ridges. Swift streams have carved out deep valleys and canyons, leaving the sloping sides in the form of projecting cliff terraces and sometimes in perpendicular rocky walls.

Mountain Structure. In some regions, notably in northern California and in southern Oregon, the ranges overlie one another like a series of blocks, which have been tilted so that the summit of one block overlies the base of the next one. Such a structure is known as **block structure.** Among such mountains the streams follow the troughs thus formed wearing out valleys with a long slope on one side and a short and abrupt slope on the other. Other mountains have a folded structure like that shown in Fig. 48-a. In this case the fold seems to have resulted

from lateral pressure. In other cases a broad, low, mountain fold or a plateau has been cut into a multitude of separate ridges by the action of streams. Such mountains are known as "dissected" ranges, and occur in all the continents. The loftiest mountain peaks in the world, found among the Alps, the Himalayas, the Andes, and the Rocky mountains, consist mainly of long layers having an upward slant and formed of tough, resisting materials. The bare and lofty summits of the Alps with their needle pointed minarets, are of the hardest granite, all the softer materials having been worn away.

Fig. 44. Cliffs and pinnacles of red sandstone left by erosion in northeastern Arizona.

In other cases mountain ranges are composed of materials so uniform in texture that the entire surface has been worn down, forming a low plateau like that occurring in New England and in other parts of the Appalachian system. Such a low, rolling, eroded surface has received the name, **peneplain** (almost a plain).

Rock Sculpture The western part of the United States affords a striking variety of sculptured rock forms. One of the most remarkable of these regions is the "Bad Lands"

of South Dakota. These consisted originally of a succession of clay beds and sandstone. Through the action of streams this region has been dissected into ridges, pinnacles, and towers of a remarkably picturesque character. The Colorado plateau also affords many examples of rocky remnants in the form of battlements and towers which appear in the distance like remains of gigantic architecture. In some cases where hard volcanic rock has filled crevices and ancient craters, the softer surrounding rocks have been worn away and the lava left in flat topped masses called plugs, or in long ridges known as **dikes.**

Fig. 45. Eroded rocks, Grand Canyon of the Colorado river.

Plateaus. The long, sloping foothills of mountain ranges and the elevated plains found among them are known as plateaus. In general, any plain above 2,000 feet in height is classed under this head. Plateaus are generally composed of a variety of rock layers in a nearly horizontal position. The most extensive plateau system of the world is found among the mountains of central Asia. These are also the highest plateaus. The United States also contains many plateaus of varying elevation. The lower plateaus

are generally good farming and grazing regions, as in the case of the Piedmont, the Allegheny plateau, and the Great Plains. The loftier plateaus are frequently deeply dissected by streams. Where this process has gone on long enough the canyons have widened into valleys bounded by low mountains and are adapted to the uses of man. The Colorado plateau on the other hand, while it has been deeply cut by that river and its branches, is a desolated region and offers no advantages to the farmer. In some cases plateaus have been almost entirely worn away and only a few flat topped table mountains with vertical sides remain. To these the names **mesas** and **buttes** are applied.

Fig. 46. A butte in North Dakota, northeast of Bismarck, along the Missouri river.

Effect of Mountains on Climate. The chief characteristics of mountain climate are **coolness** and **dryness.** As temperature falls about 1° for every three hundred feet of ascent, the loftiest mountains are regions of perpetual snow, and the cold air descending from their summits has the effect of lowering the temperature of the entire surrounding country. The best known effect of mountains on climate is the fact that they are condensers of moisture and that the regions on the windward side of them are remarkable for heavy rainfall while on the opposite side deserts are usually found, especially in the regions of constant winds. On account of the dry atmosphere and

its lightness, mountain regions are healthful places of residence for sufferers from lung diseases. The vegetation of mountain regions presents a continuous succession of species from the base to the summit. Mountains are not only a barrier to wind and rain, but they have also exerted a great influence on the history of the world by preventing intercommunication. Remarkable examples of this are the Pyrenees, between France and Spain, and the Himalayas, which separate India and China. It has taken centuries for the ingenuity of man to overcome the opposition of mountain barriers. The inhabitants of mountain regions are proverbial for their free and independent spirit, and intrenched in their inaccessible homes they have generally succeeded in defending themselves against enemies.

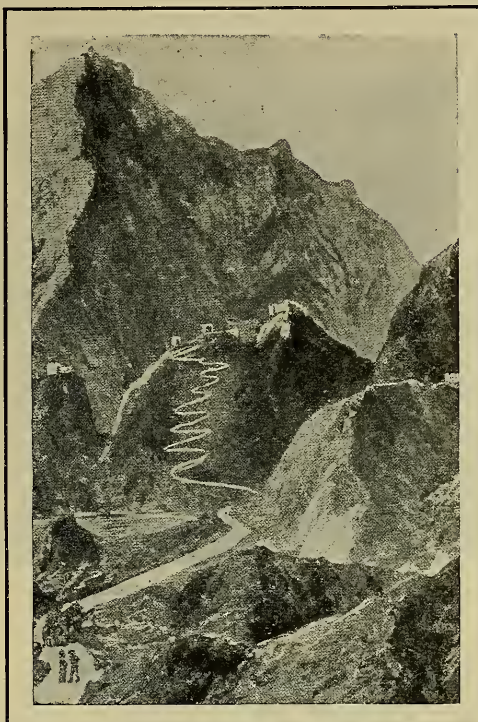


Fig. 47. The Khaibar pass in the Himalaya mountains. This pass forms the only highway between central Asia and India. It is 33 miles in length and in places only 40 feet in width. All the conquerers of India except Alexander the Great and the British entered the country by way of this pass.

Mountain Passes. In some cases mountains are crossed

by valleys which run at an angle with the ranges. These are called transverse valleys or **passes.** Two such remarkable valleys cross the Himalayas, and they have formed the highway through which invaders have descended from the

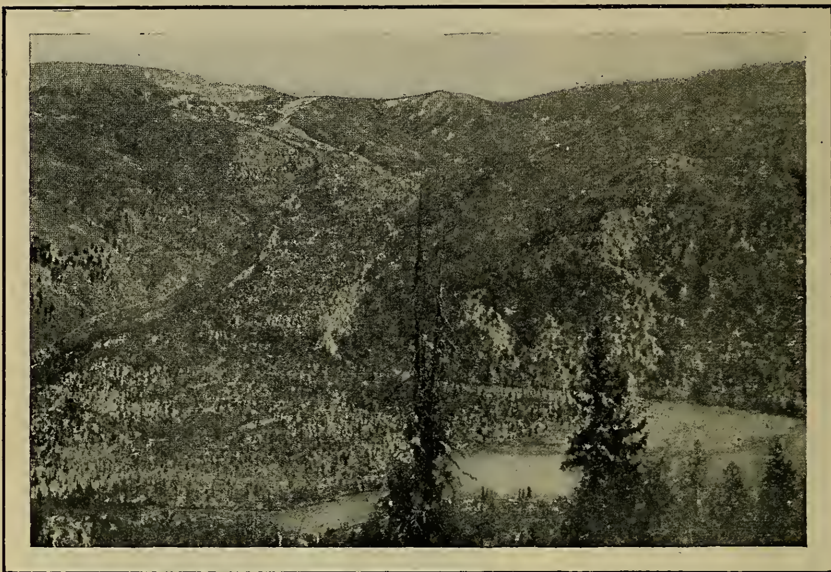


Fig. 48. A landslide in Colorado, which formed a lake by damming a stream.

north of Asia into India. The Alps also have numerous passes through which in both ancient and modern times armies have made their way into Italy.

Avalanches and Landslides. Owing to the heavy snowfall among mountains, their slopes and summits accumulate vast masses which when slightly loosened by melting slip off and fall with tremendous force into the valleys below. Among the Alps such avalanches are common, and frequently entire villages are overwhelmed by them. It often happens also that masses of earth and rocks become

loosened among the mountains and rush down the slopes for miles, destroying both men and animals and sweeping away entire forests. Landslides sometimes fill up valleys and damming the streams cause lakes to form. Sometimes they change the course of streams by filling up their usual channels. Owing to the disturbance of the strata in mountain ranges earthquakes frequently occur. The dropping of the rocks on one side of a fracture or the sudden lifting of a stratum may cause an earthquake shock which may be felt at a great distance from the seat of disturbance.

REVIEW. 1. Describe the arrangement of mountains. 2. What is said of the rock layers in mountain regions? 3. How is the formation of mountains explained? 4. What is meant by a block structure? By dissected ranges? 5. How do you account for the rugged nature of mountains? 6. What is said of sculptured forms? 7. What are plateaus? 8. Name some of the great plateaus of the world. 9. Name the chief effects of mountains on climate. 10. What effect have they had upon the history of nations? 11. What are mountain passes? 12. Describe an avalanche. A landslide.

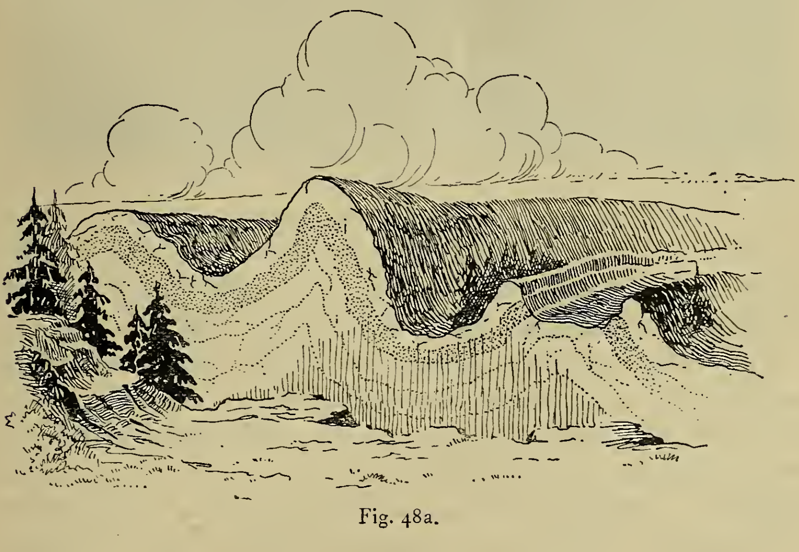


Fig. 48a.

CHAPTER IX

EARTHQUAKES AND VOLCANOES

Internal Heat of the Earth. There is abundant evidence that certain sections of the interior of the earth, are intensely heated. Boiling springs, the lava and steam from volcanoes, and the high temperature of deep mines are among the many proofs. The increase of temperature as one descends into the earth is about 1° for every sixty feet of descent. At this rate the heat would be great enough at the depth of fifty miles to melt all known rock. The enormous pressure of the crust of the earth would, however, keep the heated interior rock solid, as the melting point of solids depends on the amount of pressure upon them. But should the pressure be removed, the heated rock would immediately liquefy and flow outward as a volcano.

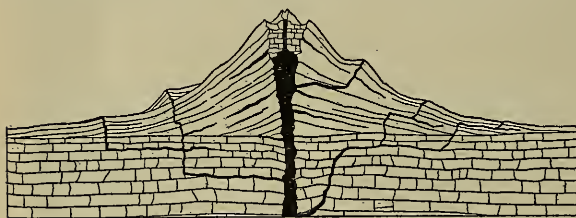


Fig. 49. Section of a volcano. The dark lines indicate the course of fractures through which the melted rock finds its way to the surface.

Volcanoes and Lava Flows are found among mountain regions in every part of the earth. The volcanoes are for the most part burned out, but many active ones still occur on the borders of the Pacific ocean and in the south of Europe. Sometimes volcanoes burst forth at the bottom of the ocean. The lava, rock, and cinders that are thrown

up gradually build up a volcanic cone, which may develop into an extensive island. **Stromboli,** near the northern coast of Sicily, is a volcanic cone which rests on the sea bottom, 3,000 feet below the surface, and is three or four miles in diameter. From a circular opening in its side, clouds of steam issue and occasionally the white-hot lava

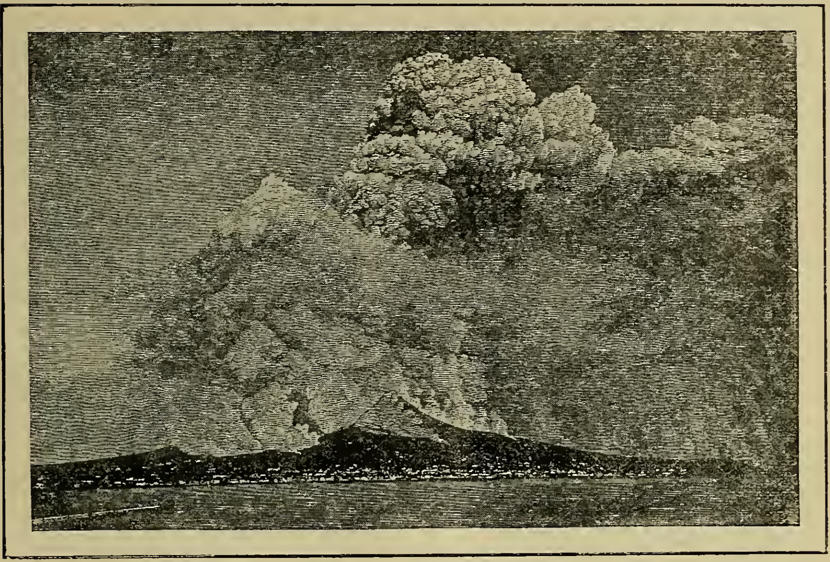


Fig. 50. Eruption at Mt. Vesuvius.

bursts out and flows down the mountain side. The explosions and eruptions are due to the formation of steam in the melted rock within the crater.

The largest volcanic island in the world is **Hawaii.** It is ninety miles long and seventy miles broad and contains two active volcanoes. One of these, Mauna Loa, 15,000 feet high, has a broad, flat top containing a lava lake forty acres in area. From its surface jets of lava are thrown to

the height of several hundred feet. At times the lava stream breaks through fissures in the side of the mountain and streams of the liquid rock several miles wide run down into the sea at a distance of thirty to forty miles.

One of the earliest and most destructive volcanic eruptions recorded is that of Vesuvius, A. D. 79, which buried the cities of Pompeii and Herculaneum. After being lost for centuries, these cities have been excavated and found to be in a good state of preservation.

A remarkable volcanic explosion occurred in 1883, on the small island

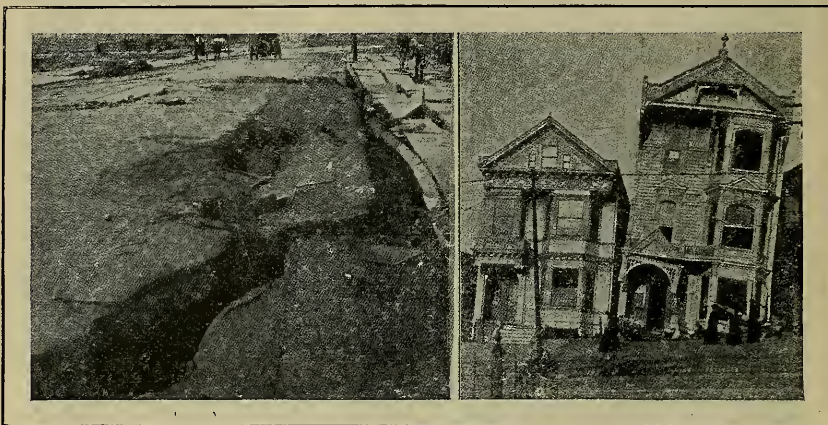


Fig. 51. Results of the San Francisco earthquake.

of **Krakatoa** in Sunda strait. The northern half of the island was entirely swept away by an explosion which was heard for several hundred miles. Enormous quantities of rock and pumice were hurled out, and the sea for several miles around was so thickly covered with floating pumice that the course of vessels was obstructed. The dust blown upward was caught by air-currents and carried entirely around the earth.

The most destructive volcanic eruption of modern times occurred on the island of Martinique in 1902. The city of St. Pierre was entirely destroyed and 30,000 people killed. The volcano of Mont Pelée stands near the city. For fifty years it had been inactive, and the people felt

secure. But on the 8th of May, a terrific stream of hot water and lava burst through a break in the crater wall, and, following a valley down to the city destroyed everything in its path. We can compare with this disaster only the eruption of Mount Vesuvius, 79 A. D., which buried the cities of Pompeii and Herculaneum.

The Cause of volcanic eruption is the formation of steam in the liquid rock that fills the craters. Water from underground channels flows into the hot lava and is suddenly turned to steam. This would cause the awful explosions that occur, and would make the liquid lava boil up and overflow. But the great lakes of boiling lava, miles in extent and of unknown depth, where do they come from? The interior of the earth is kept solid only by the great pressure of the rocks above it. Now, if these outer rocks become broken or weakened in any way by movements within the earth's crust, the hot rock below at once becomes liquid and boils up until it finds an outlet.

Earthquakes. In the process of mountain formation, as the rock layers are forced upward by lateral pressure, they are frequently fractured and the shock becomes an earthquake, which may be transmitted for thousands of miles.

Bend a brittle stick across your knee until it breaks, and notice the shock. The rumbling of an approaching train may be felt for several miles. Simple facts such as these teach us that the shock of a fractured and falling stratum might be felt over a wide area. The earthquake that nearly destroyed the city of Charleston in 1886 was felt over the entire eastern half of the United States.

Earthquakes usually occur in the neighborhood of volcanoes and are caused by the tremendous explosions which result from formation of steam within the hot craters. An earthquake shock may, however, occur any-

where. It may be caused by the breaking or falling of rock layers within the earth. Let us suppose that the interior of the earth is still cooling and shrinking while the cold and rigid crust remains firm. After a time a part of the unsupported crust drops down to fill the space left through the shrinkage of the interior. The result is an

Fig. 52. Destructive effects of the earthquake at Messina.

earthquake shock. If the fall of the stratum is no more than a fraction of an inch, the force of the shock may be felt for hundreds of miles. Again, suppose that a layer of rock perhaps many miles below the surface, is forced upward by pressure until it breaks. As the solid earth transmits motion easily, such a shock may pass entirely through it, and be felt on the other side.

Destructive Effects of Earthquakes. The most violent effects of earthquakes are felt directly over the **focus,** or seat of disturbance. From this point the shock travels outward in circles, diminishing in violence with the distance from the focus. The vibration of the earth's crust, produced by an earthquake, though slight, is often so sudden and violent as to do great damage to human life and property. Whole cities are frequently destroyed or greatly damaged, as in the case of Lisbon, Charleston, San Francisco, Messina, and other places. Great fractures sometimes are opened at the surface, followed by eruptions of hot water, mud, and sand. Sometimes the vibration has a slightly twisting motion, which is especially destructive. An earthquake under the sea is sometimes accompanied by a tidal wave which rolls inland, destroying everything in its course. Among mountain regions great masses of rock are sometimes loosened by earthquake shocks, resulting in land-slides, the obstruction of streams, and the loss of life and property.

The countries of the world most visited by earthquakes are Italy, Japan, Greece, South America, Java, Sicily, and Asia Minor. Violent earthquakes, however, have occurred in other places. On April 18, 1906, an earthquake occurred in the city of **San Francisco**, lasting one minute and five seconds. It was caused by the displacement of strata, resulting in extensive faults running parallel with the coast. The business portion of the city was almost entirely destroyed. Buildings were thrown down, railroad tracks were twisted, ridges of earth thrown up, and fissures and cracks appeared in the pavements. In some places the ground sunk a distance of six feet. In December, 1908, an earthquake destroyed the cities of Messina, Reggio, and a dozen neighboring towns and villages. Probably 100,000 persons were killed. No other earthquake so destructive of life and property has ever been known.

Hot Springs and Geysers are formed by underground waters coming into contact with the heated rock within the earth's crust. When the water flows out of the earth

steadily it is called a spring; but when it gushes out at intervals it becomes a "geyser." Geysers are found in the Yellowstone park and in the islands of New Zealand and Iceland, while hot springs are common in all parts of

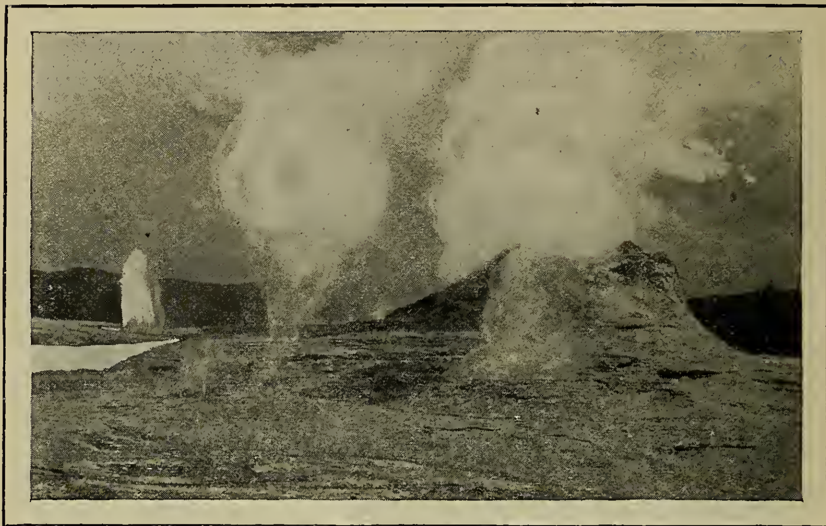


Fig. 53. Geysers in Yellowstone park.

the world. One interesting geyser in Yellowstone Park is called "Old Faithful." It spouts a mass of hot water 100 feet into the air every 65 minutes. Another geyser, known as "The Minute Man," erupts every few minutes.

REVIEW. 1. What is the evidence of the internal heat of the earth? 2. What is the effect of pressure upon the interior? 3. In what regions are volcanoes most numerous? 4. Describe the volcano of Stromboli. 5. Give instances of volcanic eruption. 6. What is the cause of hot springs and geysers? 7. What is the cause of earthquake shocks? 8. Why are they so extensively felt? 9. Describe some of the destructive effects of earthquakes. 10. In what countries are earthquakes most frequent?

CHAPTER X

EROSION AND GLACIATION

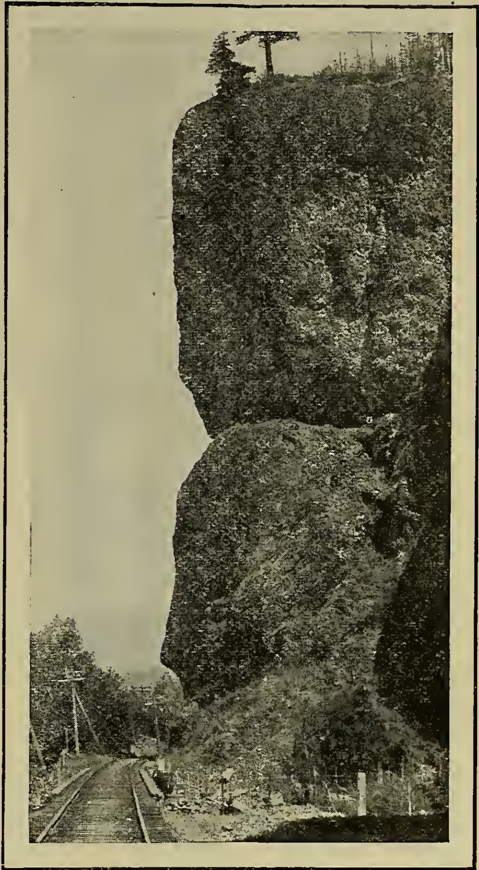


Fig. 54. A rocky bluff in Oregon. Notice the soil and vegetation on the summit of the rocks. The sides of the rock show the effects of weathering.

Erosion and Transportation. Everywhere upon the earth the land is being worn down by the action of various forces, and the worn-out materials are carried away to fill the lower parts of valleys and to build up the bottoms of lakes and oceans. The wearing-down process is called denudation, or **erosion.** It is accomplished by the atmosphere, the waters, by heat and cold, and even plants and animals share in the work. The transportation of the worn-out materials is accomplished by moving waters, the winds, and the force of gravitation.

Weathering. If we compare the surface of a freshly-broken rock with one that has been exposed to the elements, we may notice that the former is hard, shining, and compact, while the latter is dull in color, perhaps furrowed with minute crevices, and coated with loose grains which may easily be scraped off. This difference has been brought about by the action of the air and moisture, a process called weathering.

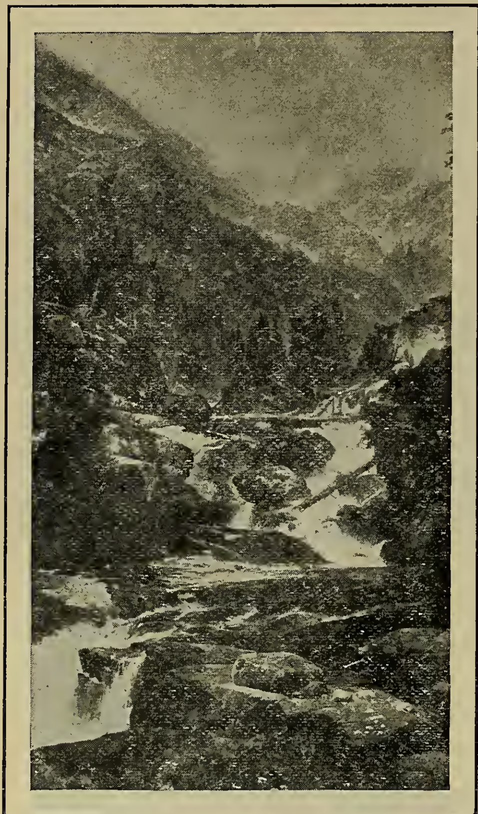


Fig. 55. Erosion by a mountain stream.

A piece of iron left in the open air soon becomes red with rust. The rust is washed off by the rain and carried away by the moving water. The rusting is caused by the oxygen of the air, which combines with the iron to form a new substance called oxide of iron. This process is called **oxidation.** Oxygen will combine with nearly everything of which the earth is made. It attacks the surface of rocks and loosens the grains which compose them. These are washed away by the rain, or fall by their own weight.

Effects of freezing. Water will soak into the hardest

rocks, and the seams and cavities with which they abound allow it to enter to a considerable distance. When water freezes it expands with irresistible force. Fragments are in this way torn from the surface of rocks, and even huge

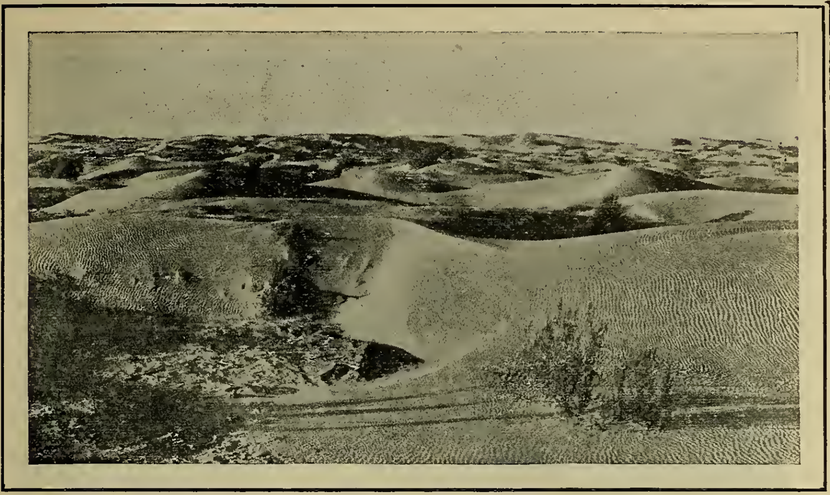


Fig. 56. Sand dunes in Arizona.

cliffs are forced apart and the pieces tumbled down. Rock expands when heated and contracts when cooled.

Sudden changes of temperature, such as occur in dry regions, cause a corresponding contraction and expansion of the rocks which splits off thin scales and small grains from the surface gradually reducing them to sand. Plants like the ivy and lichen, bushes, and small trees, strike their roots into the crevices of the rocks, gradually forcing them apart and aiding in the work of erosion.

At the base of a cliff one may often see a sloping pile of rock waste, which has gathered as the result of the agencies of erosion. Such an accumulation is called a **talus.** In dry regions, where loose sand is abundant, the winds help along

the work by blowing the sharp grains against the rocks. In Arizona the windows of houses are changed into ground glass by the sand, and telegraph poles have to be sheathed in metal to protect them from its cutting effects. Along

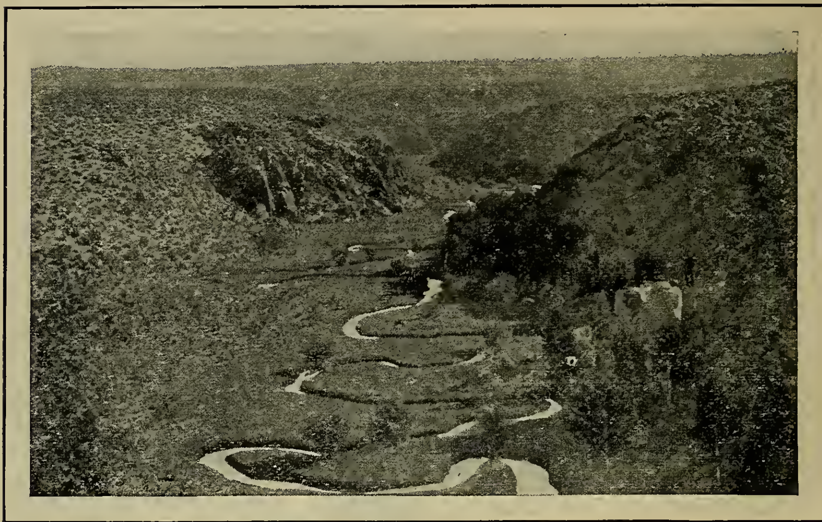


Fig. 57. Crooked Creek in Long Valley, California. A narrow alluvial plain has been formed along the creek.

sea shores and lake shores the sand is often blown inland and piled up in ridges called "sand-dunes." The Bermuda islands are largely formed of the ground up shells and sand which the wind has carried inland from the sea beaches. Along the shores of lake Michigan, the sand-dunes sometimes bury forests in their progress.

The work of the winds in grinding up rock waste and in the formation of sand hills is especially noticeable in the desert, where there is no vegetation to protect the surface. The periodical winds that sweep over the Sahara drive the sand along over the stony ground, reducing it to the finest dust and increasing its amount by wearing away the coarser material. The vast sand hills west of Egypt which continually encroach on the fertile Nile valley are blown up by the wind.

The Work of Streams. The rock waste formed by erosion is taken up and carried onward by moving waters. Every rain-storm washes it farther down the hills, until it is caught in the current of some swollen rivulet. At last the muddy rivulet joins a larger stream, which finds its way to the river and thence to the ocean. Clear water flowing through a nearly level channel does little in the way of erosion, but where the slope is steep the stream carries along stones of considerable size, the effect of which is most important. Rough fragments of rock and angular pebbles are whirled along by the swift current, ground together, and worn smooth by the friction. The bed and banks of the stream are deepened and widened by these sharp-cutting instruments, and a fresh mass of material is added to the load already carried by the swift current. By means such as these, deep valleys, gorges, and canyons have been cut out by streams, even hard rock offering little resistance to their tremendous power. When the

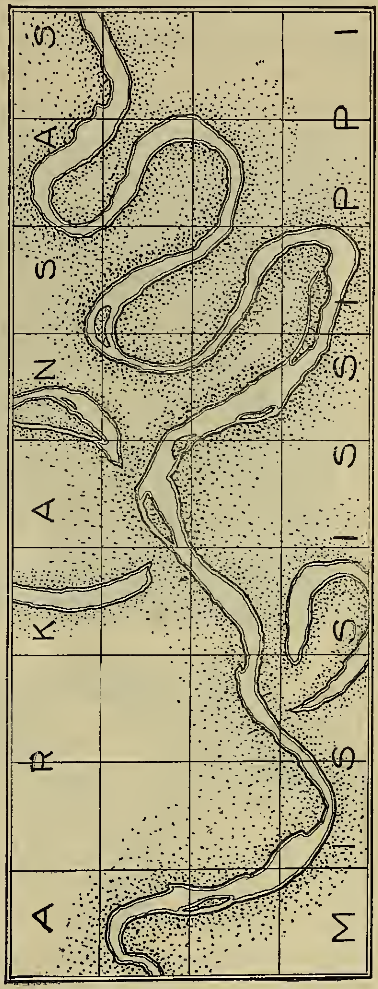


Fig. 58. The meanders of the Mississippi showing lagoons or abandoned channels.

stream reaches a lower level and the force of the current diminishes, the coarser material is dropped, and only the finer waste is carried forward by the slowly moving waters.

River Valleys. Every valley is the work of the stream that flows through it. A swift stream will cut a deep and narrow valley. But where the slope is gentle, and the stream is fed by heavy rainfalls and melting snows, it may overflow its banks in flood time and thus build up an **alluvial** or flood plain. By repeated overflows and successive deposits of sediment in the channel and near the banks, a river bed may be raised higher than the rest of the plain through which it flows. In such cases a part of the stream will at flood time often break through the banks and form a new channel. This process may be repeated many times, until, as in the case of the Mississippi river, a number of side streams, or bayous, are formed.

Deltas. The finer part of the waste carried by rivers finds its way to the sea or lake into which the stream flows. Here the force of the current is checked by the still waters, and the sediment is dropped to the bottom. In this way a large river will build up at its mouth a deposit called a delta. When the deposit begins to block the mouth

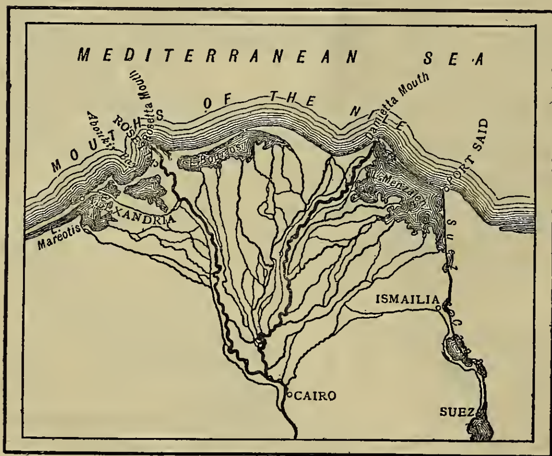


Fig. 59. The delta of the river Nile.

of the river, the stream will frequently divide into two channels, one on each side of the delta. Each of these streams may form a new delta and again divide, forming four channels. This process may continue until a dozen or more mouths, or *distributaries*, are formed (Fig. 59).

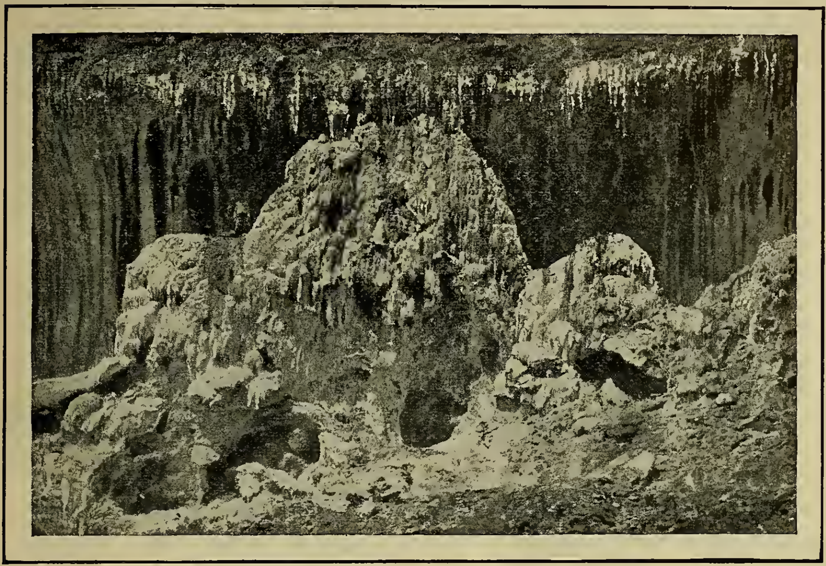


Fig. 60. A salt cavern showing stalactite and stalagmite formation.

Underground waters perform an important part in the work of erosion. A large part of the rain-water sinks into the earth. It filters through the soil to the rocks below, where it finds passages and channels which may lead it for many miles before coming again to the surface. In the course of its journey it dissolves many substances from the soil and rock through which it passes. Lime, salt, sulphur, and iron are the commonest of these. When the underground stream meets a layer of rock or clay, which is waterproof, it flows along until it emerges at the

surface as a spring. If the spring contains minerals in solution it is called a mineral spring, and may be useful as a cure for certain diseases. If the water happens to pass over heated rock it may come to the surface as a hot spring.

Caverns are formed in limestone rock because it is easily dissolved. In some regions where this is the prevailing rock the entire drainage is

Fig. 61. Glacier and lake among the Alps.

underground. The water dissolves out passages many miles in extent. These widen and deepen into great chambers, and the streams flowing through them are really subterranean rivers. Where the water filters through the roof of the cavern, it evaporates, leaving great pendants of limestone, which resemble icicles. Where the water drops upon the floor of the cave, masses of lime are built up, called **stalagmites.** These sometimes meet the **stalactites** hanging down from above and the two together form a column extending from the floor to the roof of the cavern. The Mammoth Cave, in Kentucky, and the caverns of Luray, in Virginia, are the most noted of these natural curiosities.

Glaciers are streams of ice which flow through the valleys in high mountain regions. The snow that falls upon the mountain tops in such regions, slides down into the valleys, where it accumulates until the valley is filled from side to side. Here some of the surface snow melts, and the water,

filtering through the rest of it, aided by the increasing pressure from above, changes the whole mass to ice. This ice stream moves down the valley from one to two feet per day. It carries along with it all the loose rock material which it finds on the bottom and sides of the valley. The waste formed by weathering, and the loosened stones and boulders that fall upon it are carried miles down the valley.

Fig. 62. A glacier in Alaska entering the sea.

When the front of the glacier reaches the lower and warmer part of the valley, the ice melts and becomes the source of a stream. The rock waste left behind in a mass of earth and stones at the end of the melting glacier is called a **terminal moraine.** The waste deposited along the sides forms **lateral moraines.** If two glaciers coming from different valleys happen to join, there will be a third moraine in the center. This is called a **medial** or middle **moraine.** The rocks and boulders imbedded in the bottom and sides of the glacier are scratched and polished by rubbing against the cliffs along which they pass.

Glacial Drift is the name given to the waste left by the melting glacier. The finer part of it is carried away by

the water that comes from the melting ice, and spread out over the lower valley, and is taken on to the sea by the rivers.

The antarctic regions and Greenland are entirely covered with thick ice caps. As the ice moves down to the ocean, great masses break off and float away as **icebergs.** Some of them are truly "ice mountains," being more than a mile from top to bottom. They float into warmer waters, where they melt and drop the load of earth and stones which they carry. It is thought that the fishing banks off the Newfoundland coast were partly built up in this way.

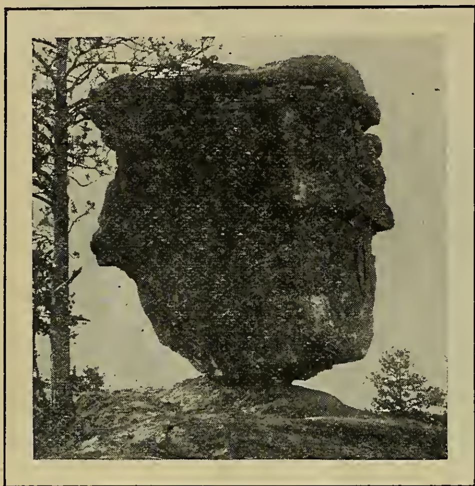


Fig. 63. A huge boulder left balanced on a cliff by the glacier.

The Great Ice Sheet of North America. Much of the northern part of the United States and a great part of Canada are partially covered with a great sheet of glacial drift. This sheet varies in thickness from a few feet to several hundred, and contains rocks and boulders that must have come from regions far to the north of their present position. Masses of copper and red jasper boulders are found in Indiana that were brought down from the shores of lake Superior and lake Huron. In southern New England the boulders appear to have come from the Green mountains to the northwest. A study of the glaciers

of the Alps long ago convinced scientific men that the drift that now overspreads northern America and northwestern Europe was brought there by moving masses of ice. The scratches upon the rocks point toward the region of Hudson Bay as the origin of the glaciers.

Cause of the Glaciers. It is supposed that the section where the glaciers originated was raised by movements of the earth's crust to such a height that the climate became as cold as that of the polar regions is now. The ice accumulated to a great depth, and moved down from the elevated regions in every direction. The tops of mountains were broken off and smoothed down, deep valleys were plowed out, streams were dammed by the huge mountains of moving ice. The soil, gravel, rocks, boulders, and waste of every sort were pushed along by the bottom

Fig. 64. Chart showing the southern limit of the great North American glacier. The arrows indicate the direction in which the glacier moved.

of the glaciers. It was like a great sheet of rough sandpaper dragged over the surface of the earth, and pushing along all the fragments loosened by its friction. When the front of the glacier reached lower latitudes, it began to melt and deposit its load of drift.

Limit of the Glacier. The map (Fig. 64) shows the limit reached by the glaciers in the United States. Along this line are found all the debris of a terminal moraine. Connecticut, New York, Ohio, and all the states along the glacial front are strewn with huge boulders that were smoothed, scratched, and rounded on the long journey.

Fig. 65. Glacial lakes in New England.

Results. When, after many thousand years, the ice melted, the valleys and troughs scooped out by the glaciers were filled with water and became lakes. The lakes of central New York occupy valleys that were thus deepened by the ice. It is thought that the melting of the ice was due to a general lowering of the surface over which it had spread. As this took place very slowly, the front of the glacier in its slow retreat continued to strew the ground with soil from its terminal moraine. The fertile farming lands

of the lake regions and the middle west are due to the rich deposits left by the glaciers.

The glaciated regions of Europe are similar to those of North America. The ice spread from the Scandinavian

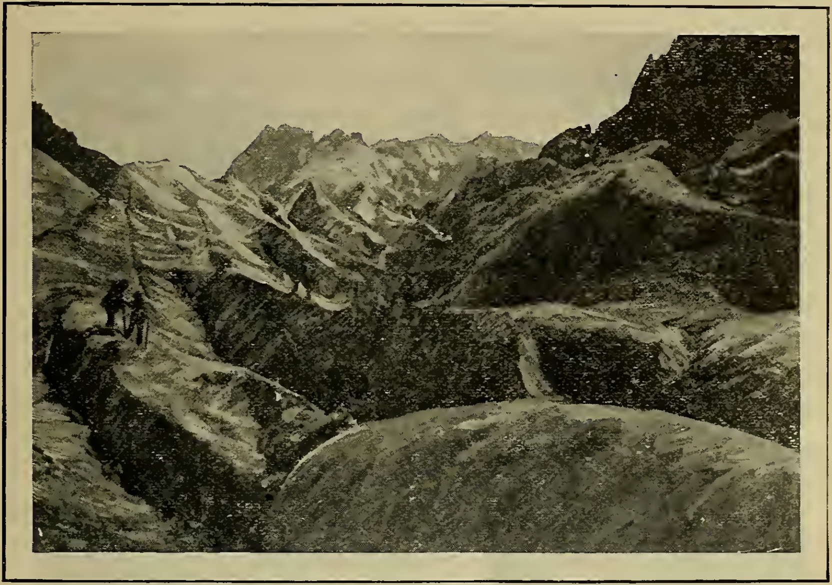


Fig. 66. Crossing a glacier among the Alps.

peninsula as a center. It filled the North and Baltic seas and reached well into central Europe before melting.

REVIEW. 1. What is meant by erosion? 2. How is it accomplished? 3. What are the agencies of transportation? 4. Tell something about each. 5. Explain what is meant by weathering. 6. How is it effected? 7. Describe the effects of oxidation and freezing on rocks. 8. How do plants help the work of erosion? 9. Describe a talus. 10. What finally becomes of it? 11. Tell how winds accomplish erosion. 12. Where are the winds most effective? 13. Describe the work done by moving water. 14. How have valleys been formed? 15. Describe the growth of a valley. 16. How are deltas formed? Name some rivers which have deltas. 17. What part do underground waters take in the work of erosion? 18. Explain how caverns are formed. 19. Stalactites and stalagmites. 20. What are glaciers? 21. Describe their erosive action. 22. Different kinds of moraines. 23. What is glacial drift? 24. How are icebergs formed? 25. Describe three effects of glaciers. 26. The North American ice sheet; its cause, location, and effects.

CHAPTER XI

THE WATERS OF THE LAND

The ocean is the original source of all the waters of the land. The rising vapor blown over the land surface is transformed into the falling rain and the various forms of precipitation. The rain, the frost, the ice, and the atmosphere, through their work of erosion and transportation, have diversified the surface of the continents with hill, valley, mountain, and plain, and fitted them for the dwelling place of man.

Fig. 67. Gorge of the Niagara river.

Drainage Systems. When rain first began to fall upon the bare rocks of the new-formed continents, it ran off swiftly in sheets and streams. There was no soil or plant life to retain the water, and therefore no springs nor permanent streams. At first the floods of rain would flow off in a single stream between two adjacent ridges. As this stream cut its channel deeper and deeper into the rock, side-streams began to carve out channels for themselves. The land gradually became deeply cut by numerous swift torrents. After a time the main stream would cut its way down to the ocean level. Its speed would then slacken and the deposit of sediment would begin at the mouth. And as the channel gradually deepened inland, the current continued to slacken, and the load of waste was deposited farther and farther up stream. As a result of the filling up of the channel, it became too small to carry the water during the rainy season. The river would then overflow at flood time and the sediment deposited would begin the formation of an alluvial plain.

During this time the hills and mountains were being worn down by erosion. Streams gnawing at their bases carried off the waste. The flood plain crept farther up the stream, until the smaller streams also began to widen their valleys. At last only the hard part of the mountains remained projecting above the plain. All the rest had been worn to fragments and spread out along the courses of streams or carried down to the ocean.

Results. Thus in changing old land into new land, a drainage, or river, system has been built up. Fertile soil has been prepared for agriculture and for the homes of men. Mountain torrents have become quiet streams, suitable for navigation. The growth of vegetation has

kept pace with the deepening of the soil and the hills and valleys are clothed with forests and varied forms of plant life.

Watersheds and Basins. If any stream be followed to its source, it will be possible to find, in the near neighborhood, water flowing in another direction. The ridge lying between two stream sources is called a **watershed,** or divide. Such divides can be traced along the headwaters of all streams. All the land that is drained into a

Fig. 68. Rapids in a river used for obtaining power.

single river is called a **basin**, and the main stream with all its branches a **river system.**

One of the largest river basins in the world is that of the **Mississippi.** It drains nearly one half of the area of the United States, and carries to the gulf of Mexico every year enough sediment to cover a square mile of surface to the depth of 270 feet. Its delta covers an area of 10,000 square miles. Each one of its thousand tributaries has its own watershed and basin, and is carrying on the work of erosion and transportation.

Lakes are bodies of water that fill depressions in the land. Some of these depressions were made through movements of the earth's crust; a far greater number were scooped out by glaciers. Lakes are most common in mountain regions. Many little valleys are surrounded by a rim of hills, and the drainage water pours into these valleys until they are full. At the lowest point in the bordering hills the overflow will break through, and the lake becomes the source of a stream.

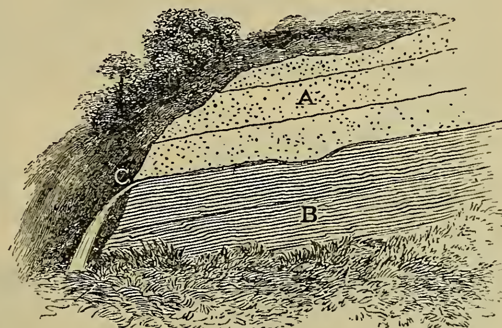


Fig. 69. Spring on a hillside. The hill is cut through, showing layers of porous rock at A and layers of clay at B.

Salt Lakes. Much of the water of a lake is evaporated by the sun. The springs and streams that feed it contain salt and other minerals in solution. When such water evaporates, the minerals are left behind. If more water flows into the lake than is carried off by evaporation, there must be an outlet, and the water will remain fresh; but if the evaporation is equal to water received by the lake, the amount of salt contained in the lake will increase and

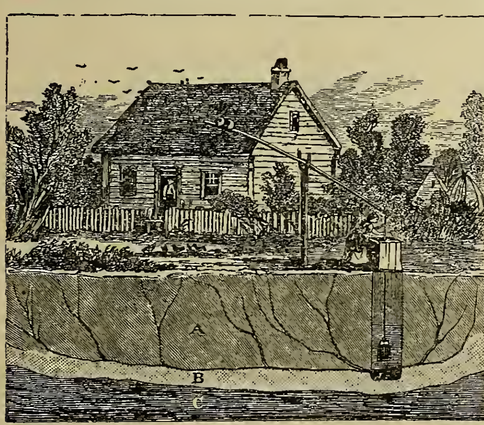


Fig. 70. Section of the earth showing how water is supplied to a well. The rock at C is waterproof.

its waters will become salty. In many cases such lakes have dried up entirely, leaving a bed of salt behind. From one such lake bottom, in the Caspian sea region, 100,000 tons of salt are annually removed. The salt lakes found in central Asia and in some regions of Africa are arms of the sea which have been cut off by the rising of the land. Such

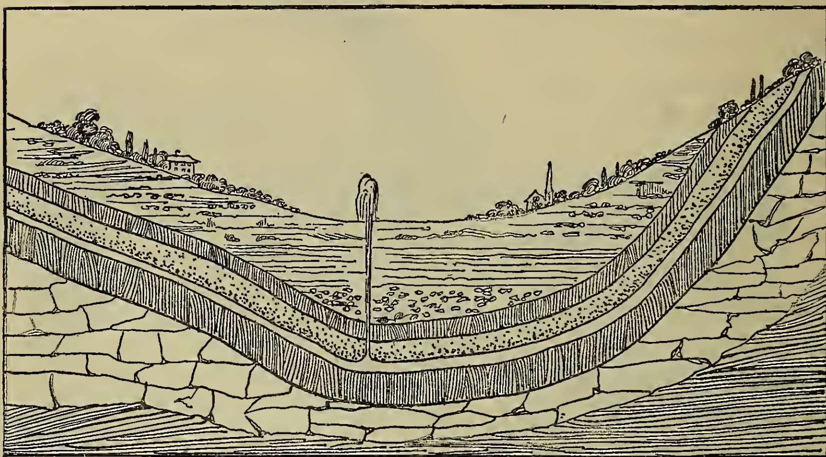


Fig. 71. Sectional view of rock strata, illustrating basin shape and source of an artesian well.

lakes are slowly drying up. The desert of Gobi is the bed of a dried-up lake.

Wells and Springs. The origin and work of springs have been mentioned (Fig. 69). A well is obtained by digging or boring down into the earth until strata are found that carry water. Such strata are said to be "permeable." If they are underlaid by "impermeable" strata, the water will be held until it can find an outlet. If a permeable stratum slopes from a higher to a lower level, it may furnish an **artesian well.** A boring is made into the earth deep enough to strike the water-bearing rock. As fast as the

boring is made, iron pipe is driven down, through which the water rises. If the outcrop of the water-bearing rock is higher than the well, the water will flow; if it is lower, the water must be pumped out.

The basin shape of the continents is favorable to the foundation of artesian wells. In the interior of Australia and in parts of Africa and the United States they are often the only source of water. Many cities obtain part of their water from Artesian wells. The water is often so cold that no ice is required in the hottest weather to make it agreeable for drinking.

Fig. 72. Intermittent spring showing siphon outlet.

An **intermittent spring** is one that flows for only a short period at a time. Its action may be understood from Fig. 72. When the water rises to the highest part of the bend in the outlet the water flows. It will continue to flow until the level falls below the outlet. The spring will then stop until the level rises again.

Relation of Rainfall to Land-Surface and Vegetation. It is clear that the amount and value of the waters of the land depend on rainfall. The erosive power of rain and streams depends on the amount of water that acts. Whether vegetation shall be luxuriant or scanty, depends also on the amount of rain received. Where the rains are too heavy, a flood plain like that of the Amazon may become a swampy jungle of little value to man. Where the rainfall is too little, as in the case of the western plains of North America, vegetation is scanty, crops fail, and flocks and

herds often starve. A moderate amount of rain at frequent intervals brings the most satisfactory results. The rivers flow to the sea and return to the earth again, keeping it suitable for the abode of man.

REVIEW. 1. Explain how the ocean is the source of the waters of the land. Describe the development of a drainage system. 2. How were flood plains formed? 3. Define watershed; river basin; river system. 4. Tell how lakes have been formed. 5. Why are some lakes salt? 6. Describe an artesian well; an intermittent spring. 7. How is rainfall related to the surface of the land and to vegetation?

CHAPTER XII

ISLANDS

Classes. About eight per cent of the land surface is composed of islands. The most of them are found near the shores of the continents and are called **continental** islands. The others lie far out in the oceans, surrounded by deep water, and hence are called **oceanic** islands. Oceanic islands are divided into **coral** and **volcanic** islands, according to their origin.

Continental Islands are thought to have once been joined to the continents near which they lie. There is much evidence to support this theory. The plants and animals of both are of the same species. The seeds of plants might have been carried across straits of considerable width, but land animals could not have passed from the mainland to these islands unless they were connected. The rocks of the continents and those of the

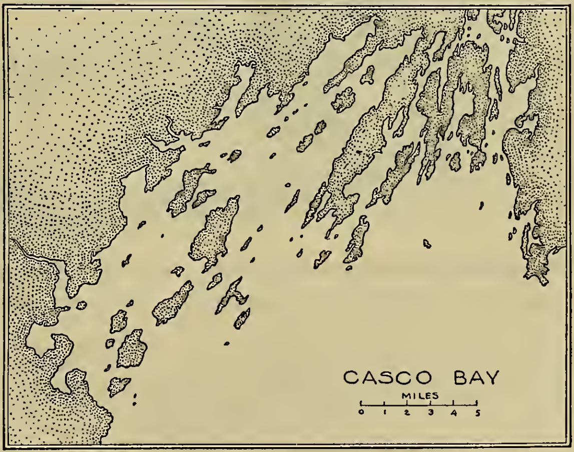


Fig. 73. Continental islands near the coast of Maine. The island chains have the same general direction as the Appalachian Mountain system.

neighboring islands are similar. The coasts of England and France, on opposite sides of the straits of Dover, are formed of chalk, a kind of limestone, and the straits are

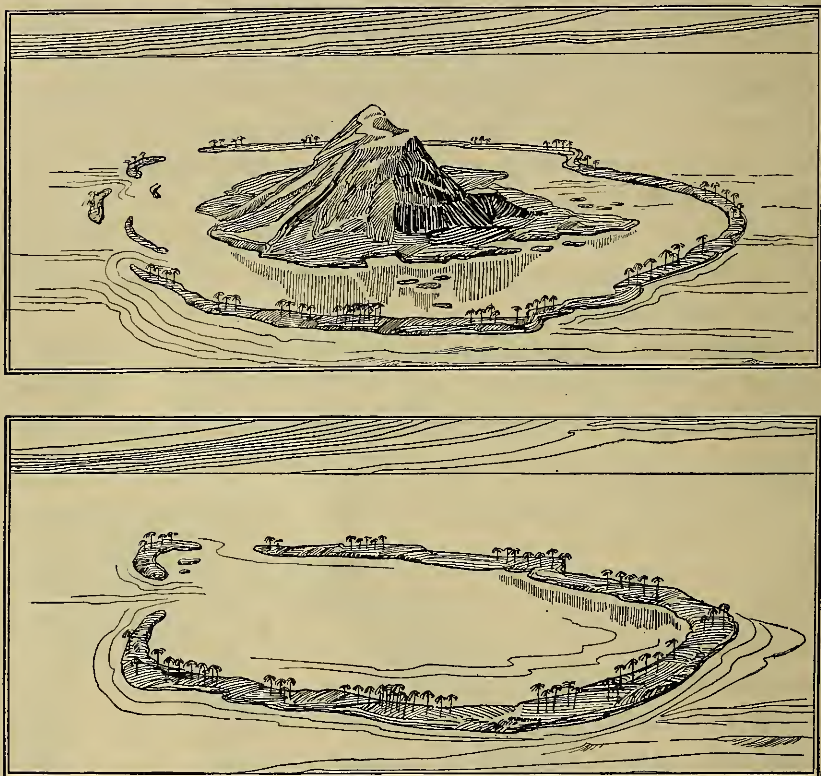


Fig. 74. Atoll formd by the sinking of a volcanic island.

not more than 300 feet deep, indicating that these countries were separated by a sinking of the land.

Continental islands appear to have been formed by a sinking of the coasts of the continents. They are usually arranged in lines parallel with the coast, or connect projecting parts of the coast. The chain of the West Indies connects the coast of Venezuela with the

southern extremity of Florida. The Japan islands and the Philippines form a continuous chain from Kamchatka to the southern coast of Asia. It seems as if a rugged coast had sunk, leaving only the tops of the mountains projecting above the water. The southern end of Kamchatka is connected by the chain of the Aleutian islands with the Alaska peninsula.

Volcanic Islands are plentifully scattered through the southern part of the Pacific ocean. Several groups are found off the coast of Africa. Iceland and the Hawaiian islands are the most extensive of this class. Many continental islands also, as for example Japan and the Lesser Antilles, are volcanic.

Volcanic islands are sometimes formed suddenly of lava and cinders thrown up from the ocean bottom. They sometimes disappear soon after forming. Some volcanic cones have been ringed with coral and made into atolls.

Fig. 75. Flower-like polyps building up a branch of coral.

Coral Islands are built by a minute animal called the **polyp,** aided by the winds and waves. The coral polyp flourishes in warm, shallow sea-water containing a little sediment. It has the power of extracting lime from the sea-water and building it up in the form of coral. Some of the coral consists of solid masses; other kinds are branching like a tree. White is the usual color, but some is of a

light red and is much used for jewelry. One of the beautiful sights among the Bermuda islands is the coral groves seen through the clear water. The sea bottom seems to be covered with red and white branching trees, while fishes, brilliant in scarlet, yellow, green, and gold, dart hither and thither among the branches.

The work of the polyp consists in the building of reefs near the shores of continents and islands. If the reef is close to the shore, it is called a **fringing** reef, but if at a distance, a **barrier** reef. There is a great barrier reef off the coast of Australia 1,200 miles long. The sea between a reef and the shore is smooth and in places forms a good harbor.

Fig. 76. Red coral formation.

The **atoll** is a curious circular reef built by the polyp around the crater of extinct submarine volcanoes, or off the shore of an island which has afterward sunk.

A barrier or fringing reef would be changed into an atoll by a slow sinking of the island around which it is built. During the sinking, the coral is all the time growing, so that in time there would be a ring of coral surrounding a shallow lake. This coral ring is the foundation of the atoll. The drift of the sea lodges among the branches; the pounding surf breaks off pieces of coral which fall into spaces below and help to bring the reef above the water. The seeds of plants are borne to the reef by the winds and waves. They take root and grow and add their remains to the

rising mass. Finally, when palm-trees begin to flourish and there is fruit enough to support life, men come to make their homes on the atoll.

REVIEW. 1. Name the three classes of islands. 2. Location of continental islands. 3. What is the evidence that they were once a part of the continents? 4. Name the chief groups of continental islands. 5. What is the origin of volcanic islands? 6. Describe the growth of coral islands. 7. Atolls, fringing and barrier reefs.

CHAPTER XIII

THE COAST LINE

Importance. Nothing is more important to a commercial country than the character of its coast line. The great increase in ocean traffic and the size and draft of modern vessels make it necessary to have deep harbors and to take precautions against dangers from the shoals, sandbars, rocks, and reefs, which are found on every coast. The care of the coast is given to the general government. The United States Coast Survey provides charts of the coasts, showing the depth of waters and the accurate location of every coast feature of importance to navigation. Many millions of dollars are spent each year in deepening channels and harbors, and in building breakwaters and jetties to keep them clear and safe. Lighthouses and signals are built on dangerous coasts, and bell-buoys and lightships are anchored over hidden reefs. Each port has its trained pilots to conduct ships safely into the harbor, and life-saving stations are established along the coast to rescue those who have suffered shipwreck.

Changes in the coast line are always in progress. Some of these are the work of the restless ocean itself; others are the result of the rising or sinking of the land. The sediment brought down by the rivers may form sandbars at their mouths, or may be dropped farther off shore, to be afterward raised up in the form of island barriers. The ocean floor near the coasts of continents is thickly strewn with the deposit of rivers. This sediment builds up a plain beneath the waters. A rising of the coast would bring this plain above the surface as a coast plain. The sediment which has been deposited assumes a variety of forms. Some of it is shaped into long lines by the movement

of the ocean waters; other forms are delta-shaped, with the longest side toward the ocean.

The southern part of the Atlantic coast of North America, after a long period of rising, is slowly sinking again. Its rising brought the ocean floor to the surface as a coast plain, and quickened the flow of rivers, which cut deeper channels and brought down a larger amount of sediment. The results of sinking have been the formation of swamps and marshes along the coast and the deepening of the mouths of rivers. When the bed of a river sinks below sea level it is called an **estuary**, or drowned valley. The Thames and the Hudson rivers are examples of drowned valleys that are excellent harbors. The Atlantic coast plain increases in width from New York all the way to Texas, but from the north to south it is increasingly flat and swampy and the sinking has not yet progressed far enough to make good harbors.

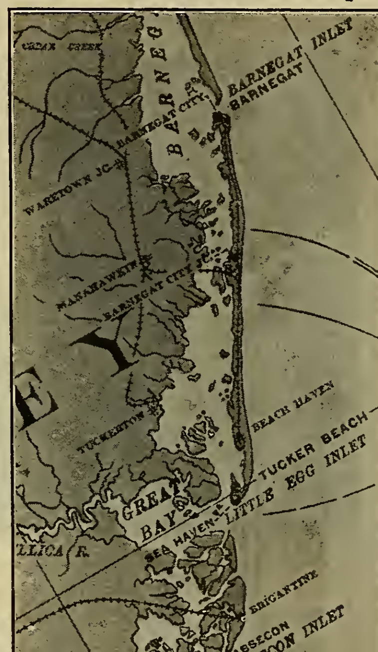


Fig. 77. A part of the coast of New Jersey, showing islands and beaches formed from sand.

An interesting proof of the sinking of the coast is furnished by the buried cedar forests along the New Jersey shore. Every traveler along the Pennsylvania railroad has noticed the stumps and logs lying in the marshes. The cedar grows

only on high ground. Hence the coast must have been once raised many feet above its present position.

Fiords. Along rocky shores, where the mountain ranges make an angle with the coast, the sinking of the land allows the sea to flow up the long, narrow valleys, forming **fiords.** These are numerous along the coasts of Norway, Alaska,

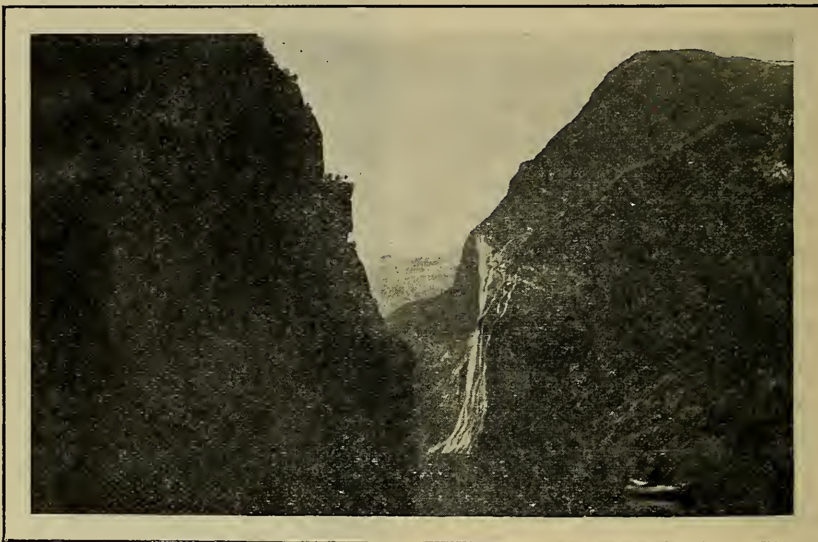


Fig. 78. A fiord on the coast of Norway.

and the southern half of Chile. In Scotland they are called **firths.** Where the tide rises to a considerable height, it flows back and forth through these long inlets, making them deeper and wearing away the softer parts of the rocks, often cutting them into curious and fantastic forms. Caverns of great beauty are often carved out. The dash of the waves and currents carries off the worn-out material, often leaving pillars of hard rocks known as "stack."

Effect of Waves and Currents. The ceaseless dash

of the waves and currents against the shore and the grinding up of the rocks and pebbles by the surf form a vast quantity of sand in addition to the sediment brought down to the sea by rivers. This mass of fine, worn-out matter is shaped by the currents which sweep along the shore into various forms. Where the river empties into a sea that has no currents, a delta is made. But in most cases the currents are stronger than the rivers; then the sand will be piled up in a long bar across the river's mouth. Or if the direction of the ocean currents is parallel with the shore, the silt will be swept away from the mouth of the river and spread out in long lines along the coast. Sometimes a bar will be formed, partly closing a bay; it is then called a **spit.** Occasionally by the action of two currents it is bent in the form of a curve or hook; it is then known as a **hook,** or hooked spit.

Fig. 79. Cape Cod, a hook formed from sand through the action of the tides and waves.

REVIEW. 1. What is the value of the coast line? 2. What provisions are made for the safety of ships? 3. Describe some changes always in progress along the coast? 4. Rising and sinking coasts and proofs. 5. What are fiords? 6. Describe the formation of sandbars, as to origin and deposition of the sand. 7. Peculiar forms of bars.

CHAPTER XIV

THE SEA

General Description. The sea is the continuous body of salt water surrounding the globe and enveloping the land masses on every side. The continents make four divisions of it which we call oceans. The Pacific ocean is nearly equal in size to the other three, and is the deepest, averaging 2¾ miles. The deepest sounding ever made was 31,600 feet, near Guam. The ocean bottom is nearly a continuous plain. There are gentle elevations and deep depressions, but it has been said that a railroad could be run around the world on the ocean floor without any grading. This fact makes it easy to lay down telegraphic cables, so many of which now stretch across the ocean floors in every direction. The sediment from the rivers does not reach far beyond the borders of the continents, but the greater part of the ocean bottom is overspread with the remains of plants and animals which have sunk.

The greater part of the sea is open to **navigation,** but the regions around the poles are filled with floating ice. This ice helps to keep the waters cold, but prevents free navigation in those parts. The **icebergs** that break from glaciers and float away with the ocean currents are among the dangers that beset the sailor. The **sea level** is taken as a standard by which to measure the heights of the land and depths of the sea. When we speak of a mountain 5,000 feet high, we mean so many feet above the sea level, and not that the top is 5,000 feet above the base.

Temperature and Pressure. The temperature of the ocean depends on latitude and depth. The deep waters vary only slightly from the freezing point, being 29° in the polar regions and 35° at the equator. The heating effects of the sun do not reach lower than 600 feet, and the waves and tides that disturb the surface do not affect the water below a depth of 100 feet. The temperature of the surface waters varies from 80° F. at the equator to a freez-

Fig. 80. An iceberg off the Coast of Newfoundland.

ing temperature at the poles. The salt of the sea makes the water a little heavier than fresh water. One hundred pounds of sea water contains 3½ pounds of mineral matter, the most of which is common salt. It is thought that sea water has been salt from the beginning; but it must be growing more and more salt because vast quantities are carried into it every year by rivers.

Pressure in the depths of the sea is very great. At a depth of two miles, it is two tons to the square inch. Since the density of water does not increase with depth, the pressure at a depth of one mile would be one ton per

square inch. The pressure of the air upon our bodies is 15 pounds per square inch. At a moderate depth it would be impossible for a human being to live. When deep-sea fish are brought to the surface they are killed at once by the change of pressure. Their bodies crack open and their eyes bulge out.

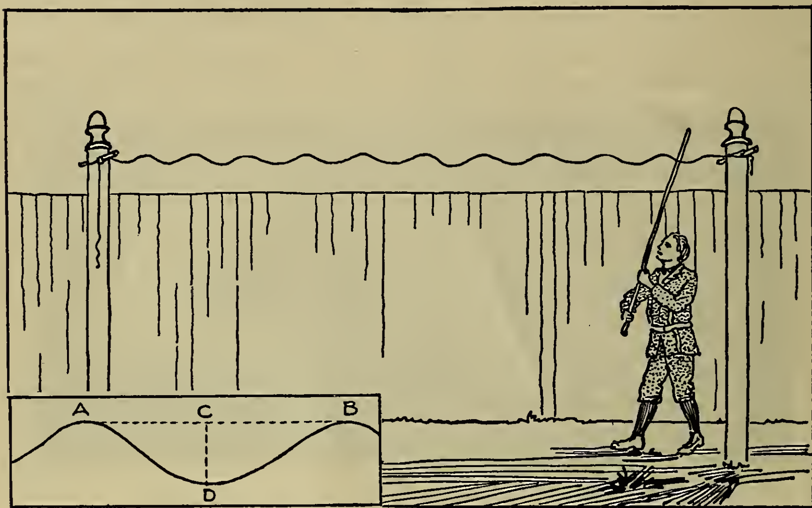


Fig. 81. Wave motion caused by striking a line. C D equals height of wave; A B equals length of wave.

Movements of the Water. Water is easily set in motion. The lightest breeze upon its surface will cause a vibratory movement. A jar or shock within the earth's crust, such as may accompany an earthquake or a volcanic eruption, will cause waves of extraordinary height and destructive force (page 57). It is almost proverbial that water is never at rest, and the sounds which one may hear by the sea are infinite in number and variety. You may not be able to detect any cause for the motion of the surface of the water or of the surf and breakers which strike

against the shore, for the disturbing force may be many miles away.

Fill a pail with water and strike a slight blow against the bottom or side and notice the effect on the water. Throw a stone out into a pond or pool of water and observe the effect.

Waves, Breakers, and Surf. Waves consist of an up-and-down movement of the surface of the water, caused

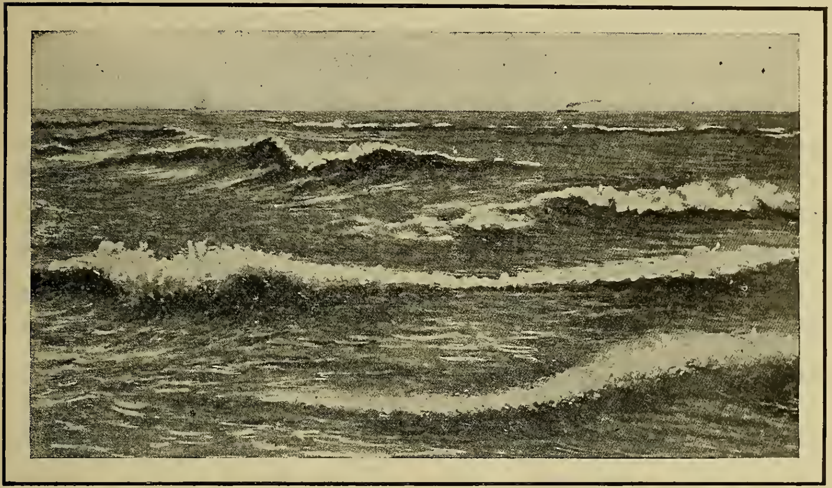


Fig. 82. Breakers forming near the shore

by the winds which are continually blowing against it. The varying pressure of the wind causes the water to vibrate with a slight motion backward and forward, but there is no onward movement of any mass of water. It is merely the wave motion that moves onward, just as we may observe it when the wind blows over a field of tall grass or grain. The stalks vibrate backward and forward, but the *motion* appears to sweep entirely across the field.

We may illustrate wave motion by attaching a cord to hooks on opposite sides of a room and drawing it moderately taut. If we strike

the cord with a stick at one end, a motion resembling that of a wave will travel its entire length. The method of measuring dimensions of waves is shown in Fig. 81. The summit of the wave is called its "crest" and the bottom of the wave its "trough." The height is the perpendicular distance between crest and trough and the length is the distance from crest to crest.

The height of waves varies with the force of the wind. In violent storms waves sometimes occur fifty feet in height and over a thousand feet long with a rate of speed varying from forty to sixty miles per hour. Small vessels are frequently swamped by such waves, and even the largest steamships are sometimes seriously damaged.

When waves approach the shore and enter shallow water, the front of the advancing crest becomes steeper and steeper until it falls forward upon the beach, forming a **breaker.** The foaming water then rolls up farther inland as **surf.** The ceaseless flow of the surf back and forth and the pounding of the breakers on the beach grind up the pebbles and shells into the finest sand. On steeply sloping shores the waves strike with great violence, breaking cliffs to pieces and sometimes destroying buildings, piers, and other structures.

Tides. Anywhere at the seashore one may observe the regular rising and falling of the water level. During six hours the water rises farther and farther up the sloping beaches, or higher and higher on docks and piers, until the "high water" mark is reached. For the next six hours the level falls, and we have "low water." On the open sea, far from land, the rise of tide does not exceed one foot, but at the shore its height varies with the direction of the coast line, it being greatest in inlets with converging sides and least on points and headlands.

Causes. It was observed many centuries ago that the recurrence and height of the tides corresponded with the position and phases of the moon. The scientific proof of this relationship, however, was the result of the applica-

tion of Newton's Law of Gravitation. The tides are caused by the attraction of the moon for the mass of water forming the oceans. Water being mobile, the hydrosphere is drawn out into the form of a prolate spheroid (page oo), and as the earth rotates beneath the moon from west to east this spheroidal shell of water has an apparent motion in the opposite direction. That is to say, the tides travel around the earth from east to west once every twenty-four hours. As there are two "high tides" on opposite sides of the earth and two "low tides" at a distance of 90° from these, it follows that a high tide and low tide will succeed each other every six hours.

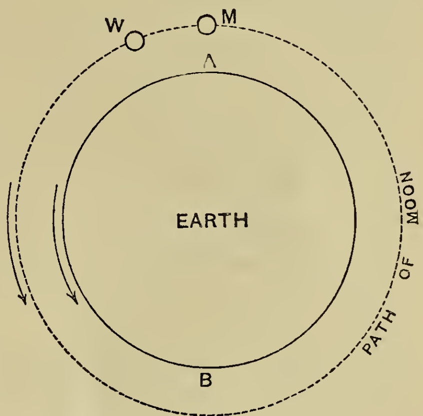


Fig. 83. Illustrating the cause of variation in the recurrence of tides.

As a matter of fact, the succession of high and low tides requires twenty-four hours and fifty minutes to pass around the earth. Thus any point at the seashore has high tide about fifty-two minutes later each day. The reason for this may be understoodby study of Fig. 83. While the earth is rotating on its axis, the moon is also revolving about the earth in the same direction. As the revolution of the moon requires about twenty-eight days, it will be overhead on any point of the earth about fifty-two minutes later each day. When the moon occupies the position M, the points A and B, directly underneath it and on opposite sides of the earth, will have high tide. Now, if the moon remained at rest, point A would come underneath it every twenty-four hours, but during this period the moon has moved onward to W, and fifty-two minutes longer are required for points A and B to be brought into a straight line with the sun.

Effect of the Sun—Spring and Neap Tides. The attraction of the sun also causes a tide in the same manner as the

attraction of the moon; but, although the sun is much larger than the moon, it is so far away that the solar tides are only two fifths as great as the lunar tides. When the sun, the moon, and the earth are in the same straight line, as shown in Fig. 84, the attractive forces of the sun and moon are exerted in the same direction, and the resulting tide is known as **spring tide.** The spring tides occur at the time of new moon and full moon. When the sun and moon are

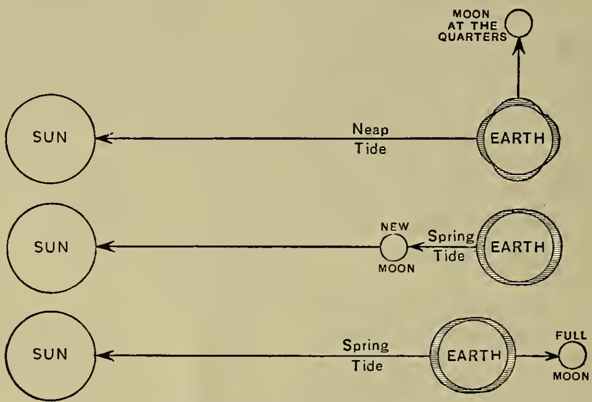


Fig. 84. Spring and neap tides.

in the first position shown in Fig. 84, they attract the water in directions at right angles to each other, and the result is a lower tide than usual, called **neap tide.** The recurrence and height of the tides are further complicated by the variation in the distances of the sun and moon from the earth and in the angles which their orbits make with each other. The great variation also in the depth of the oceans and in the configuration of the coast produces an endless variety of tides, and each place has its own conditions which must be studied in order to determine accurately the time and height of its tide.

Effects of Tides. The tides are of service to navigation in the periodic deepening of harbors and mouths of rivers, thus allowing vessels of greater draft to enter and leave port. They help to purify the water by keeping it in motion and thus bringing every part of it into contact with the oxygen of the air. But the tides also carry sediment along the coasts, sometimes depositing it at the mouths of rivers and harbors, whence it must be removed at great expense and trouble. Where tides flow through narrow channels they sometimes form swift and dangerous currents, called **races,** which flow alternately back and forth. When the tide enters the mouth of a river having a strong current, the water rises in a high mass called a **bore,** which travels up stream with great swiftness, often wrecking small vessels and doing damage along the coast.

Ocean Currents. Not only are the surface waters of the ocean disturbed by waves and tides, but the entire mass of oceanic waters takes part in a vast and comprehensive system of movements, called currents. By means of these currents, the cold waters of the polar regions are brought toward the equator, and the warm waters of the equatorial regions toward the poles, thus tending to equalize both the temperature and saltness of the waters. Through this transfer of cold and warm waters, the temperature of the winds is also affected and the climate of the lands over which they blow.

The movement of the surface currents of the ocean corresponds so nearly with the direction and force of the winds that these are considered to be their principal cause. Along the equator, for example, the currents have the same direction as the trade-winds, flowing westward until they are interrupted by the shores of the continents. The

direction of coast lines is a second important cause of the direction of currents, since the water on striking the coasts must follow their direction.

When the **north equatorial current** (Fig. 85) strikes the coast of South America and Asia it is deflected northward, following the trend of the coast. After crossing the tropic of Cancer this current becomes known as the Gulf Stream in the Atlantic ocean, and the Japan Current in the Pacific ocean. These currents, on coming into the region of

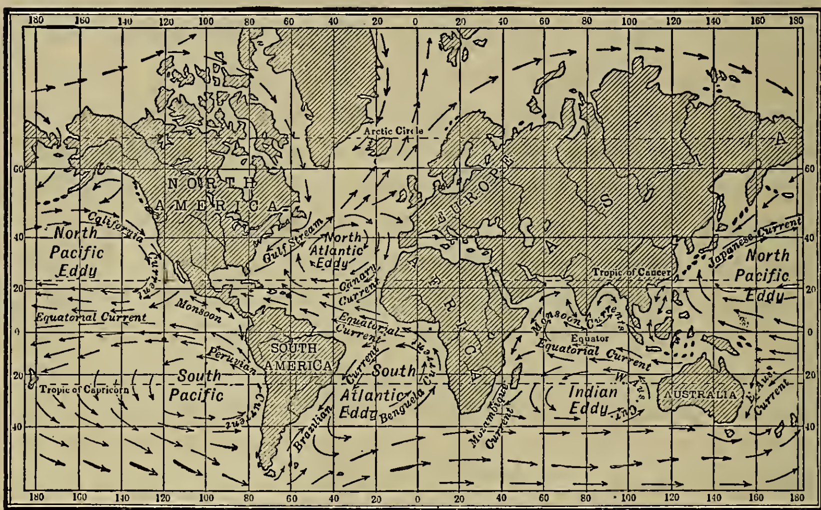


Fig. 85. Chart of the ocean currents.

westerly winds, are bent eastward until their waters strike the shores of North America and Europe. On the coast of Europe the Gulf Stream divides, part of it passing into the Arctic ocean, and a part returning toward the equator. The passage through Bering strait being narrow, the entire Japan Current is bent southeastward by the western coast of North America, and returns again toward the equator.

The **south equatorial current** may be traced in a similar manner as shown in Fig. 85. In the Pacific ocean it is deflected southward by the coast of Australia, and in the Atlantic by the shore of South America. As a result, these currents turn to the southeast and join the drift or return currents flowing eastward. In the Indian ocean, south of the equator, the ocean currents make a circuit, which is much like

that in the Atlantic and Pacific. An important feature of the currents of the Indian ocean is the effect of the periodic winds or monsoons, These currents are north of the equator and change their direction twice a year, soon after the change in the direction of the winds. This fact is accepted as conclusive proof that currents are mainly the result of the winds.

Other Causes. It is no doubt true that ocean currents are affected by a difference in the specific gravity of the waters, caused by variations in temperature and saltness, and by the rotation of the earth. The great heat and heavy rainfall of the equatorial regions tend to make the water lighter. It therefore rises and flows in the circuit described above, while the heavier water from the colder regions returns toward the equator as deep-sea currents. The rotation of the earth would tend to set up a flow of currents in the same direction as the winds.

Counter or Return Currents. The westward trend of ocean currents in the regions of the trade-winds tends to bring about a return current along the equator in the regions of calms. The regions of calms along the tropics are marked in each ocean by sluggish westward currents, which with the other currents described, form whirls or eddies, into which immense masses of seaweed and other floating debris of the ocean are drawn, giving these places the appearance of grassy seas.

Effects of Ocean Currents. The chief effects of ocean currents are seen in the climate of the bordering countries. A study of the chart (Fig. 85) shows that the western sides of the oceans are heaped up with water which has been warmed by its passage westward across the ocean under a tropical sun. The winds that traverse these warm waters are necessarily heated and loaded with water vapor, resulting in the heavy rainfall of tropical

regions. Again, as these warm waters are distributed, they return into the regions of westerly winds, and the climate of Europe, the western coast of North America, and other temperate countries are supplied with heat and moisture. On the eastern shores of Asia and North America are cold currents, which descend from the Arctic regions, and these coasts are correspondingly cold. The cold water, however, is favorable to the principal varieties of fish and are the most valuable fishing grounds in the world. In the days of sailing vessels ocean routes were laid out as nearly as possible along the ocean currents, but the influence of these currents is of little importance on steam navigation, and the courses of steamships are now determined by other considerations.

The ocean currents from the Arctic regions bring with them vast masses of ice in the form of **floes** and **icebergs.** Such masses transport the stones and soil which they have taken up in their journey across the land as glaciers. When the ice melts this material is of course distributed over the ocean floor. We thus see that the ocean, by means of its winds and currents conveying heat and moisture, and by means of the life which it supports, is of the greatest service to mankind. As a highway for vessels it carries the commerce of the world, and its cooling breezes and moderate climate are sought by thousands in pursuit of health.

REVIEW. 1. Describe the sea, giving its chief divisions, depth, nature of its floor, etc. 2. What is said about the sea level? 3. Temperature of the ocean at different depths and latitudes. 4. Quantity of salt in the sea. 5. How does pressure vary in the sea? 6. Why is it so great? 7. Describe the mobility of water. 8. How is the water of the ocean disturbed? 9. What is a wave? How caused? How measured? 10. Describe the effect of breakers and surf along the shore. 11. Describe the phenomena of the tides seen along the shore. 12. What is the chief cause of the tides? 13. Explain their recurrence. Why later each day? 14. Effect of the sun on tides. 15. What is the cause of spring and neap tides? 16. Describe the effects of the tides. 17. What is the chief cause of ocean currents? 18. What other causes can you mention? 19. Describe the course of the equatorial currents in the northern and in the southern hemispheres. 20. Trace the Gulf Stream and the Japan Current. 21. What is the cause of counter-currents? 22. Write a paragraph on the effects of ocean currents.

CHAPTER XV

THE ATMOSPHERE

Composition. Air is a mixture of gases. **Oxygen** and **nitrogen** are the most abundant, forming $\frac{39}{40}$ of the whole. Carbon dioxide and water vapor are next in importance. Besides these, there are several other gases found in small amounts. Oxygen is the most important substance in nature. It composes $\frac{1}{5}$ of the weight of the air, $\frac{8}{9}$ of the weight of the water, and, by combining with other substances, makes up fully ½ of the whole earth. It supports both plant and animal life, and causes fire to burn. Dissolved in water, it supports the life of the ocean, though some animals like the whale come to the surface to breathe.

Gently warm a tin cup of water and the dissolved particles of oxygen will be expanded and driven to the surface. They may be seen clinging to the bottom and sides of the vessel.

Carbon Dioxide. When animals breathe or when fire burns, this gas is formed. Carbon dioxide supports plant life just as oxygen supports animal life. The plant retains the carbon and gives up the oxygen, while animals by respiration inhale oxygen and give out carbon dioxide. **Nitrogen** composes about ¾ of the weight of the air, but is not important, its use being chiefly to dilute the oxygen. The amount of water vapor in the air at any given time varies according to place and temperature.

Pressure and Weight. The atmosphere encompasses the earth on every side and penetrates into all cavities of the earth. We do not know how high above the earth it

extends, but ⅞ of its weight is within ten miles. Its densest layers are next to the earth, and it grows thinner and lighter as the distance from the earth increases. It

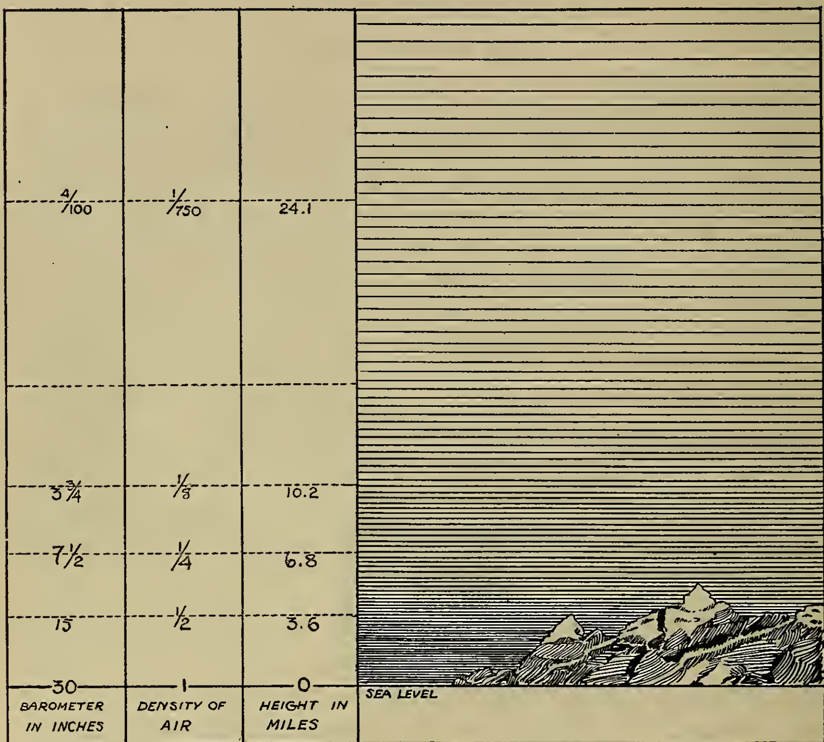


Fig. 86. Chart showing the density of the atmosphere and the height of the barometer at different elevations.

is known, however, to reach a height of several hundred miles, though human life cannot exist at a greater height than seven miles.

The **barometer** is an instrument used to measure the pressure and weight of the atmosphere. A glass tube (Fig. 87) is closed at one end and filled with mercury. When the tube is placed upright, it is found that the mercury remains at a certain height in the tube. What keeps

it there? Clearly it must be the downward pressure of the air at the open end of the tube on the surface of the liquid at A. If the end of the tube were 1 square inch in area, the mercury column A B would weigh 14¾ pounds. That is, a column of air 1 inch square at the base and extending upward as far as the atmosphere reaches, weighs 14¾ pounds at the sea level. For convenience, the barometer tube is much smaller and the column of mercury is 30 inches high. When the barometer is carried into elevated regions, the mercury falls about one inch for 1,000 feet of ascent. It may thus be used to measure the height of mountains. Its other use is in connection with the weather (see page 128).

The temperature of the air is measured by the **thermometer.** This is a closed tube with a bulb at one end, and contains mercury. The space above the mercury, as in the barometer, is a vacuum. Since the mercury expands when heated and contracts when cooled, temperature is measured by the rise and fall of the mercury column. There are several forms of the thermometer. One commonly used is Fahrenheit's, in which the boiling point of water is marked 212° and the freezing point 32°. In the Centigrade thermometer, the boiling point is marked 100° and the freezing point, 0°.

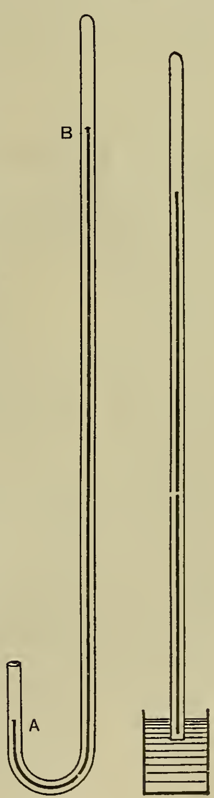


Fig. 87.
The Barometer.

Forms of Moisture. The moisture in the air comes from the evaporation of water upon the earth or sea. This process goes on at all temperatures, so that the air always contains more or less moisture. The air and the moisture it contains act like a great blanket to keep the earth warm. Without them, the earth would soon lose its heat and would become too cold to support life of any kind.

Moisture in the Atmosphere. The air always contains a greater or less amount of moisture depending upon its temperature. Warm air is able to contain more than cool air, and evaporation continues until the atmosphere contains all it will hold. At this point it is said to be saturated. A cubic foot of air at 50° F. contains about four grains of water vapor. At 70° it contains eight grains. At 100° it will hold about twenty grains.

The moisture of the air is usually in the form of invisible vapor. During the day evaporation goes on rapidly; damp surfaces are dried and water vapor from the ocean is taken up freely by the air. When air which is saturated is cooled, it gives up a part of its moisture in the form of rain, snow, etc.

Humidity. We commonly speak of the moisture of the atmosphere as humidity. The actual amount of water vapor present in a unit volume of air is called its *absolute* humidity, and the ratio which the absolute humidity bears to the quantity of vapor which the same amount of air would contain if saturated is called *relative* humidity.

Fill a tin vessel with ice and water. Stir the ice through the water until dew begins to form on the outer surface of the vessel. Then insert a thermometer into the mixture and after a minute or two read the temperature. This will be the same as the surface of the cup outside and of air which is in contact with the cup. The temperature at which moisture begins to condense out of the atmosphere is called the **dew point.**

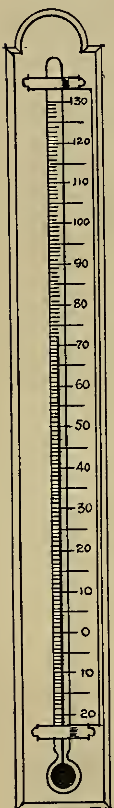


Fig. 88. A Thermometer.

Forms of moisture. When the invisible vapor of the atmosphere is cooled it condenses slightly and becomes visible vapor. When this occurs at the surface of the earth, such vapor is called **fog,** or **mist,** but when it takes place at some distance above the earth it is called **cloud.** Fogs and

mists are usually seen in the morning when the surface of the earth is cooled. But after the rising of the sun warms the earth they change to invisible vapor. As clouds and fogs are partially condensed vapor, they are heavier than the invisible vapor, and hence tend to settle down through the air toward the earth. When, however, they reach the warmer layers of the atmosphere they change into invisible vapor, and disappear.

Varieties of Clouds. Clouds have several forms, which may be grouped into four classes. The high, feathery clouds, called **cirrus**, are composed of small ice crystals—so small that they are kept afloat at the height of several miles by the air currents. The clouds that we frequently see

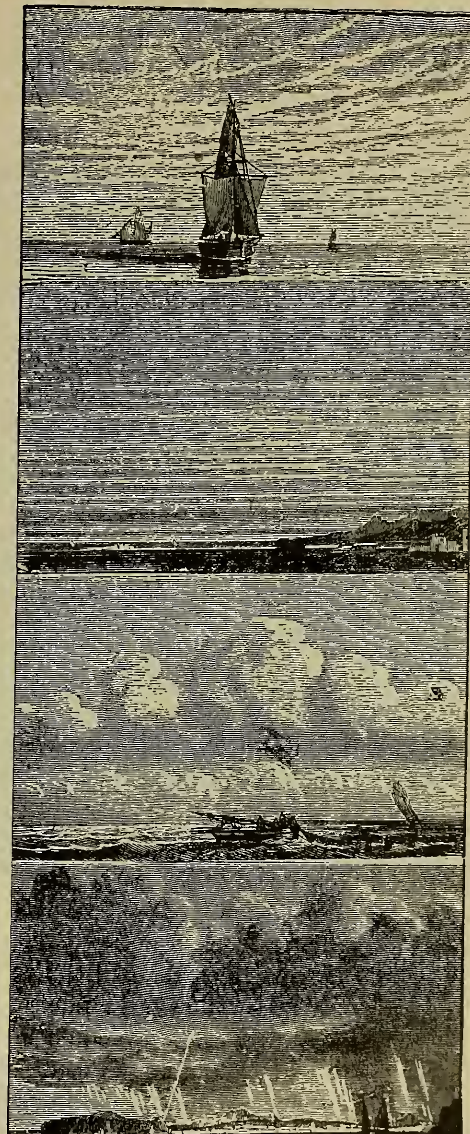


Fig. 89. Forms of clouds. 1. Cirrus. 2. Stratus. 3. Cumulus. 4. Nimbus.

along the horizon arranged in long lines are called **stratus,** or layer clouds. The heavy, dark masses of clouds which often precede a summer thunder-storm are called **cumulus** clouds. Clouds which are being condensed into rain or snow are called **nimbus** clouds. They may be seen as light gray ragged masses traveling rapidly before the wind that brings a shower. They are usually condensed portions of cumulus clouds.

Rain, Snow, and Hail. All clouds consist of water vapor in a partial state of condensation. When the particles of moisture become so heavy that the air can no longer support them, they fall in the form of rain, snow, or hail. If a partially condensed cloud passes into a layer of air below the freezing point, the little particles of moisture expand into crystals and fall as snow. The snow crystals take on many curious forms, but all of them are six pointed, thus having an angle of sixty degrees formed by two adjacent branches. (Fig. 90)

When vapor condenses above the freezing point, rain is formed. When the condensing drops of vapor fall through layers of air below the freezing point, the result is hail. Hailstones are often built up of successive layers, evidently having fallen through alternate layers of vapor and cold air. They are sometimes an inch or more in diameter and resemble irregular masses of partially compacted ice.

Dew and Frost. As we have seen, in the experiments above, when air comes in contact with any substance below the dew point the water vapor condenses out of it in the form of dew. If the condensation takes place in a temperature below the freezing point the vapor is deposited in the form of frost.

The common expression, "the dew falls," is incorrect, as dew forms by the condensation of moisture from the air which touches the objects where the dew appears. Neither is frost formed by the freezing of dew, but by the deposit of minute ice crystals on objects in contact with the air from which the crystals are precipitated. On clear nights

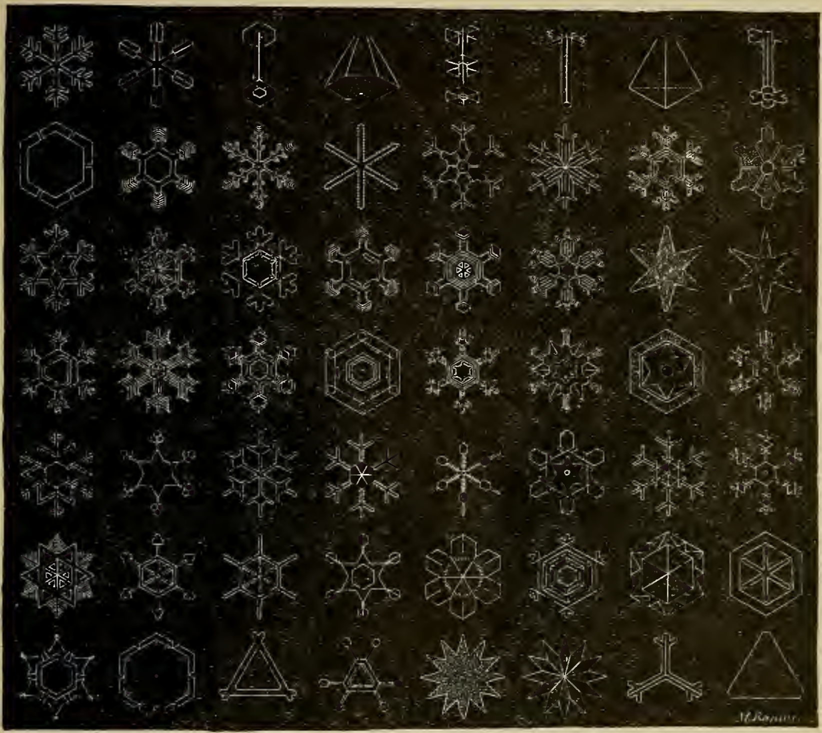


Fig. 90. Forms of snow crystals.

more dew will be deposited than on cloudy nights, because clouds prevent the radiation of heat from the earth and the objects on it. In the same manner any form of protection, as paper, cloth, a tree, or cover of any kind, will help to retain the heat and prevent the formation of dew or frost. Objects which radiate heat quickly, such as leaves, grass, metals, and stones, will have a heavier dew upon them than objects which retain their heat. Much of the dew is deposited from moisture which rises from the earth. Hence lowlands and swamps will have heavier dew than hilltops, because more moisture rises from

them and also because the air in the valleys is heavier and colder than the air on the higher ground. The cold air settles down into the low places and the warmer air rises to the higher places. Air movements prevent the formation of dew by carrying away the moisture as soon as it turns to vapor. A still, clear night is the most favorable for the formation of dew and frost.

REVIEW. 1. What are the chief gases composing the atmosphere? 2. How can you show that water contains oxygen? 3. How is carbon dioxide formed and what becomes of it? 4. Why is the atmosphere densest at the surface of the earth? 5. What is the height of the barometer at a distance from the surface? 6. What does this show about density? 7. Describe the construction of the barometer. 8. What are its chief uses? 9. Describe Fahrenheit's thermometer. 10. How is the centigrade thermometer constructed? 11. What would be the result if the earth had no atmosphere surrounding it? 12. How is climate affected by a lack of moisture in the air? Compare desert climates. 13. How are clouds formed? 14. Mention and describe four varieties of clouds. 15. Define fog, mist, dew, frost, hail, rain, and snow.

CHAPTER XVI

TEMPERATURE AND PRESSURE

Heat Belts or Zones. The temperature of the earth and the atmosphere above it depends mainly upon the direction of the sun's rays. If it depended on this alone, these rays would divide the earth's surface into **five heat belts** or zones. When the sun is farthest north, its perpendicular rays would trace the tropic of Cancer, its horizontal rays the Antarctic circle. When the sun is farthest south, its rays would in like manner trace the tropic of Capricorn and the Arctic circle. This would give one hot zone, two temperate, and two cold zones.

Unequal Heating. The unequal heating of the earth is due to several causes besides latitude. The most important of these is the fact that land takes up heat quickly and loses it quickly, while water takes it up slowly and loses it slowly. The effect of this principle alone would be to make the land very hot in summer and very cold in winter, while the water would have a moderate temperature throughout the year. The movements of the water tend to counteract the effects of unequal heating. As we have seen (page 95), the cold waters of the ocean flow toward the equator and the warm waters toward the poles. The **uneven surface** of the land affects temperature in several ways. For every 300 feet of elevation, the temperature will be one degree Fahrenheit colder. Hence the mountain regions will be cooler than the lower plains. The **direction** of mountain ranges affects temperature. If

they extend east and west, they may shut off the cold winds from the polar regions and make parts of the land warmer. The central plain of North America owes its cold winter to the fact that the mountains run north and south, and thus allow the cold winds to sweep down from the north.

Isotherms (equal heat lines) are lines which divide the earth into true temperature belts. They are drawn across the earth from east to west, connecting all places having the same average temperature for any given time. Thus we may have isotherms for the whole year or we may have winter and summer isotherms. If the temperature of a place is taken every day in the year at the same hour, and the sum of these records divided by 365, we shall have the average annual temperature of the place.

Heat Belts Movable. A study of the isotherms for January and July will show that the heat belts or zones are not fixed, but that they move north in summer and south in winter, following the sun. The isotherm of 80°, which crosses the United States in July, is found at the equator in January, 40° of latitude farther south. If we compare the isotherms of the land with those of the ocean, we shall find that the shifting north and south is much less on the ocean. The rains and winds are, like temperature, partly dependent also on the direction of the sun's rays. Rain belts and wind belts therefore shift north and south, following the sun.

Atmospheric Pressure, as before mentioned, is measured by the barometer. At the sea level the mercury column averages 30 inches; this is taken as the standard of pressure and is called "one atmosphere." The pressure of the atmosphere is due to its actual weight; and this varies

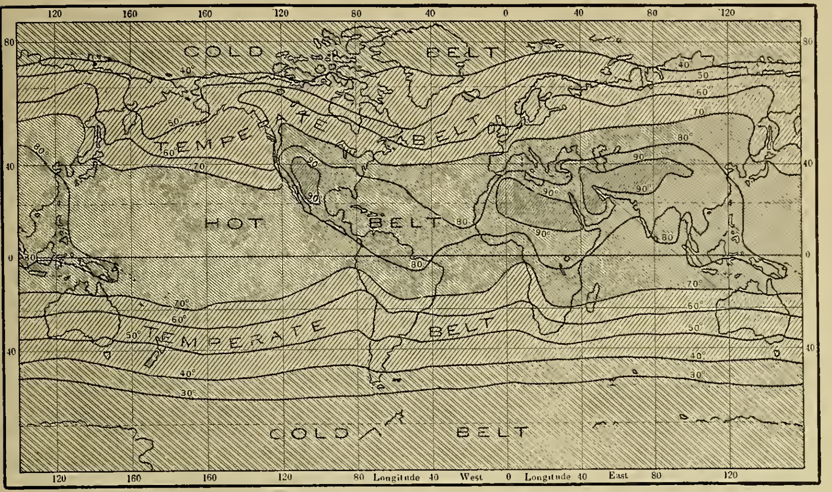


Fig. 91. The heat belts in July.

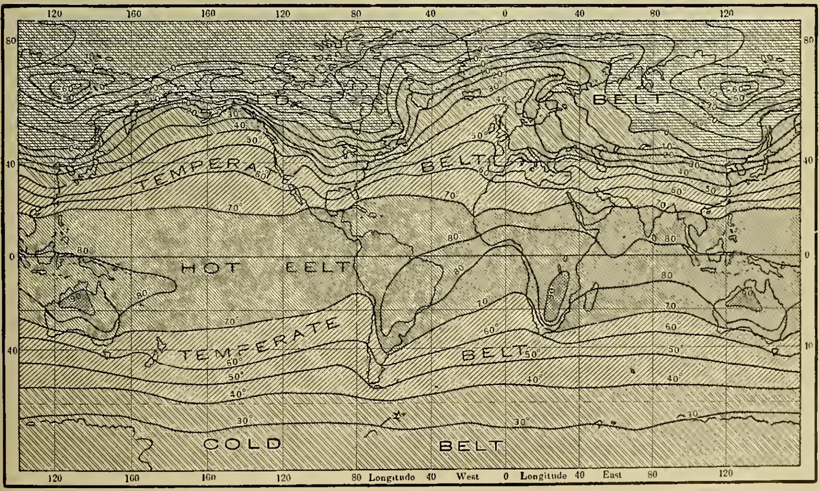


Fig. 92. The heat belts in January.

according to temperature and the amount of water vapor that the air contains. A rise of temperature and decrease of vapor make the air lighter. The temperature and pressure of the air are of great importance because they help us to understand and predict the force and direction of winds and storms, and the occurrence and amount of rain and snow.

Isobars are lines connecting places on the earth having the same atmosphere pressure. They are named by giving the reading of the barometer at these places. The important use of isobars is to determine the direction and velocity of the wind. Winds blow from high pressure to low pressure, as shown by the arrows that cross the isobars (page 129). The velocity of the wind will depend upon the variation in pressure, or **gradient.**

REVIEW. On what does the temperature of the earth mainly depend? 2. Give the location of each of the five heat belts according to latitude. 3. What is the effect on climate of the ability of land and water to take up and retain heat? How do the waters of the ocean help to distribute heat? 4. How does elevation affect temperature? 5. Effect of mountain ranges and valleys on temperature. 6. What are isothermal lines? 7. Trace the isotherm of thirty degrees for January (Fig. 92) and account for its irregularity. Trace, also, the isotherm of sixty degrees for July. 8. Trace the thermal equator for each of these months, and compare its course with that of the geographical equator. 9. Compare the position of the heat belts in January with the corresponding heat belts in July. 10. What is meant by atmospheric pressure? 11. How is it measured? 12. What are isobars? 13. How are they located and named? 14. How do isobars determine the direction of the wind? 15. What is meant by gradient?

CHAPTER XVII

WINDS, RAINS, AND STORMS

Cause of Air Movements. The atmosphere is kept in continuous motion through the unequal heating of the earth and the resulting inequalities of atmospheric temperature and pressure. Warm air is lighter than cool air; hence it rises, while the cool air flows in to take its place. If we open a door between a cold room and a warm room the cold air will flow along the floor into the warm room and the warm air will flow along the ceiling into the cold room. This process will continue until the air of both rooms is of uniform temperature. It is a matter of common observation that the heated air near a lamp, a stove, or any other source of heat, is continually rising and that cool air is flowing in toward the source of heat. Thus the effect of unequal heating is to establish a circulation of air by which a uniformity of heat is established.

The regions of the earth lying along the equator are intensely heated by the direct rays of the sun. In these places, therefore, the heated air is rising and flowing both north and south toward the colder regions of the temperate and frigid zones. From these cold regions, currents of cool and heavy air are flowing along the surface of the earth toward the equator to replace the rising and pole seeking currents. As the warm currents travel through the upper air to the poles, their temperature falls; and as the cold currents travel southward along the surface toward the equator, their temperature rises. It follows

that a point will be reached where the north seeking currents will descend to the earth and where the currents traveling toward the equator will rise into the upper atmosphere. This place on the earth is in the neighborhood of 30° north and south of the equator. As the currents of air are either rising or sinking at these places, they are regions of calms. At the equator, also, where the air currents are rising, there is a region of calms. The diagram (Fig. 93) shows the general circulation of the atmosphere if the earth had a uniform surface and no movement of rotation. Owing, however, to the differences between land and water and to the rotation of the earth, the actual circulation of the atmosphere deviates greatly from the system shown in the diagram.

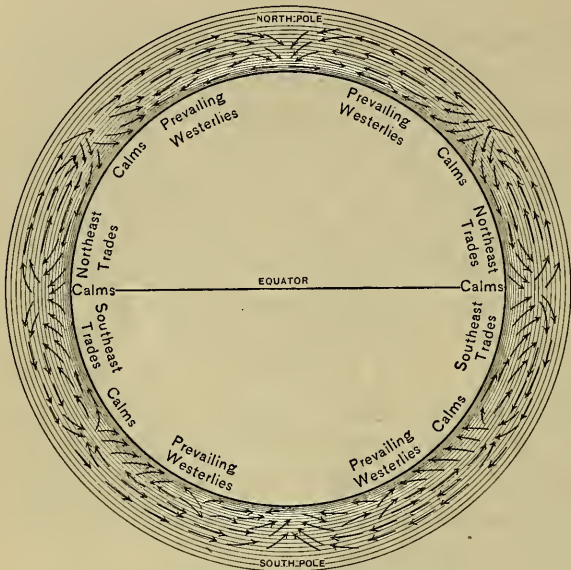


Fig. 93. Constant winds and calms.

Effect of the Earth's Rotation. The velocity of the earth's rotation at the equator is, as we have seen, about 1,000 miles an hour, and diminished to zero at the poles. Though the atmosphere is drawn toward the center of the earth by the force of gravitation, it is the lightest and most movable part of the earth's substance. Hence,

while the earth rotates toward the east, the atmosphere, being less firmly held by attraction than the solid and liquid parts, has a motion in the opposite direction. This opposite motion would be greater in the regions of the earth having the greatest velocity of rotation. The movement of the air currents upon the earth is extremely complicated and the causes are not fully understood. The westward currents set up along the equator by the earth's rotation turn northeastward in the northern hemisphere and southeastward in the southern hemisphere. Their effects die out in the regions of the tropics. Beyond the tropics the winds are uncertain and irregular until the latitude of forty degrees is reached. At this point the winds blow steadily from the west with a tendency toward the polar regions. As they approach the poles they tend to whirl spirally about them in the direction of the hands of a clock in the south polar regions and in the opposite direction in the north polar regions.

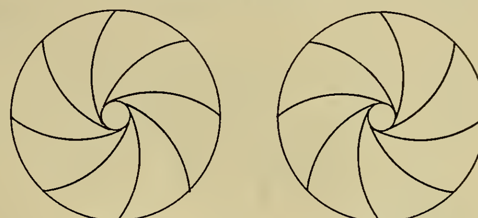


Fig. 94. Effect of rotation of the earth on the direction of air currents. The cut on the left shows the effect on currents moving from the equator toward the poles. The cut on the right shows the effect on currents moving from the poles toward the equator.

The effect of the rotation of the earth in deflecting air currents from the north and south direction may be illustrated by rotating a globe from west to east. While it is in motion draw lines along a meridian from the equator toward the poles. We shall have a series of curves which bend eastward, increasing their curvature as they approach the poles. In a similar manner if lines are drawn from the poles toward the equator they will curve toward the west. This teaches us that the pole seeking air currents are bent eastward and that those moved in the opposite direction are bent westward.

Classes of Winds. The currents of air moving west-

ward and turning to the northeast and southeast are known as the **trade-winds.** Since they blow steadily throughout the year, they belong to the class called **constant** winds. To this class also belong the prevailing westerly winds of the temperate regions. Between the region of the trade-winds and that of the westerlies, the winds are uncertain and changeable. Hence these are regions of **variable** winds. The constant winds of the earth are sometimes known as **planetary** winds, because they belong to the planet as a whole. These wind belts shift north and south, following the sun as it moves back and forth between the solstices. Hence the areas of both constant and variable winds are continually changing.

Periodic Winds are those which reverse their direction according to the change of seasons or as the result of unequal heating. **Monsoons** are periodic winds, caused by the shifting of the heat belts of the earth. The monsoons of the Indian ocean are the most noted (Fig. 95). During the northern summer the equatorial heat belt shifts north of the equator and the southeast trade-winds bend eastward, becoming the southwest monsoons. During the northern winter, when the heat belt shifts south of the equator, the northeast trades bend eastward, becoming the northwest monsoons. This variation in the direction of the winds is partly caused by the rotation of the earth and partly by the intense heating of land masses, by which the winds are drawn toward the heated regions. As the monsoons sweep across the Indian ocean they carry with them vast masses of vapor which condense to rain in traversing the land. The direction of all classes of winds is affected by the direction of river valleys and mountain

ranges. The winds tend to blow parallel with the valleys and with the ranges, following the paths of least resistance.

Land and sea breezes are periodic winds caused by unequal heating of land and water along the coast. As the land is heated more rapidly than the water, the currents of air are drawn toward the land during the day, forming a sea breeze. At night the land cools rapidly while the water retains its heat. The result is a land breeze. Sailing vessels take advantage of the land breeze by leaving port before daybreak.

Rainfall. The general theory of rainfall and its distribution has already been discussed. The vapor rising from the ocean is blown landward with the wind, and is condensed by meeting the cold air of elevated regions or by being carried into the upper and colder layers of the atmosphere. The amount of evaporation depends upon the intensity of the sun's rays and upon the movement of air over the surface of the ocean. The capacity of the air to retain vapor depends also upon its temperature. The following general laws may be laid down in regard to rainfall: 1. Rainfall is greatest at the equator and diminishes toward the poles. 2. The rainfall on the coasts of the continents and on the windward sides of cool slopes and mountains is greater than on interior plains. 3. In the region of the trade-winds, the greater rainfall occurs on the eastern slopes and coasts of the continents. In the region of the westerly winds the rainfall is greatest on the western slopes.

The Tropical Rain Belt. A study of the rain chart (Fig. 95) shows that the region of heaviest rainfall lies along the equator. The trade-winds blowing from the northeast and southeast bring vast quantities of vapor

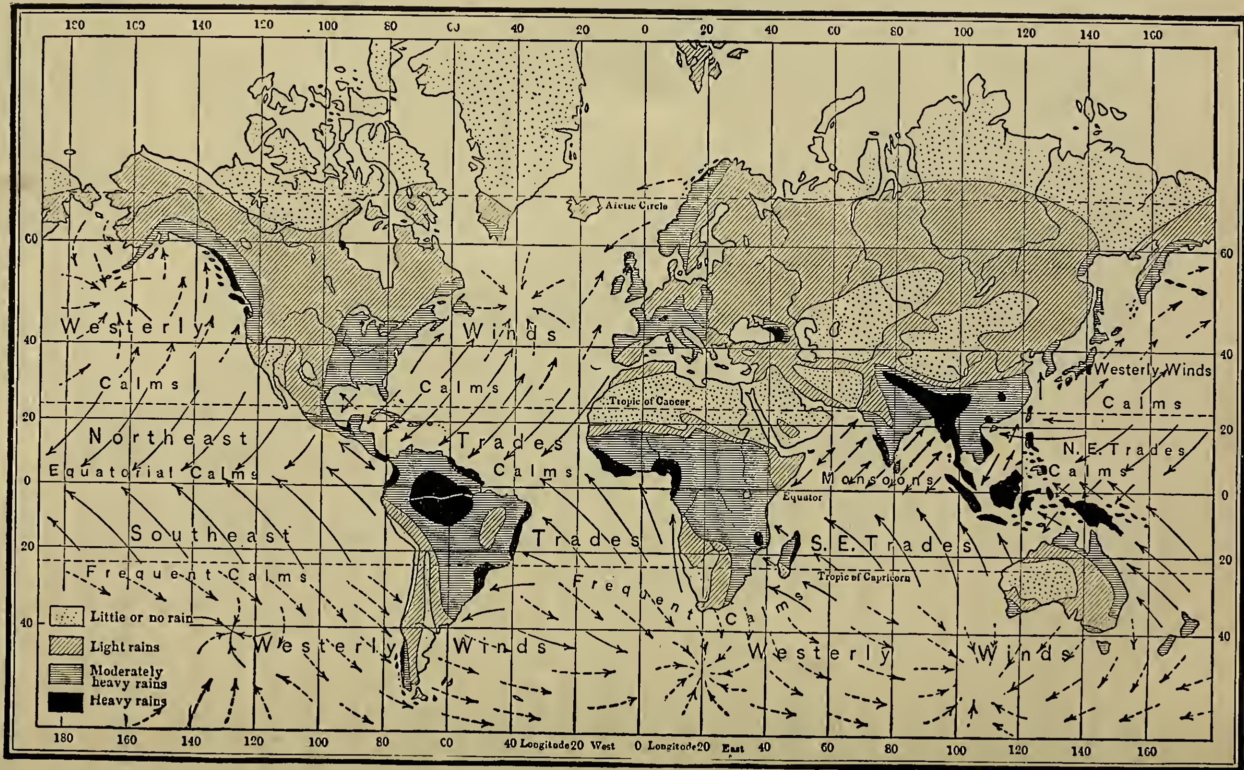


Fig. 95. Chart showing the wind belts and rainfall.

into this region and the rising currents of air carry it to a sufficient height for condensation. In many parts of the tropical regions, rains occur daily. A study of the charts (Figs. 91 and 92) shows that the region of tropical rains shifts northward during our summer and southward during our winter, which is the summer of the southern hemisphere. This regular movement of the rain-belt produces the wet and dry seasons of the tropics. It will be noticed that the region of calms bordering the equator is traversed twice a year by the rain belt, and hence will have two wet seasons and two dry seasons annually. In the regions beyond the equatorial belt of calms the wet season comes in summer and the dry season in winter.

Desert Belts. When winds pass over elevated regions, the moisture is largely condensed from them by the cool atmosphere. When after passing such regions, the winds descend again to lower plains, they become warm and able to take up more moisture. Thus they become **drying winds,** and the land over which they pass is usually barren. It is in this way that the Sahara and most other deserts of the world are caused. Such regions are barren not because the soil is unfertile but because of the lack of moisture. The so-called desert regions of the United States have proved, when irrigated, to be wonderfully productive. Occasionally deserts are crossed by low mountain ranges which arrest enough moisture to fertilize the soil and to feed streams of considerable size. Such streams flow during rainy weather, but for the rest of the time they are dry gorges and are frequently used as roads.

Rainfall Beyond the Tropical Belt. The rainfall in the temperate regions of the earth is subject to great variations due to local causes. The western coast of North

America and the greater part of the continent of Europe are watered regularly by rains brought by the prevailing westerly winds. The interior regions of North America are dependent upon the northern limit reached by the tropical rain belt and upon the eastern limit reached by the westerly winds. As these limits are variable, so the regions dependent upon them for moisture occasionally suffer from drouth. The eastern part of North America, having no mountains to interrupt the force of the winds, has a rainfall varying from 60 inches at the gulf of Mexico to 30 inches at Hudson Bay. The source of the rain is mainly the great cyclonic whirls which originate in the tropics. The regions of Europe and of Asia lying far from the coast or hemmed in by mountain ranges are necessarily dry.

The rainfall of any region is measured in inches per year. When it reaches 40 inches and is well distributed throughout the year, agriculture may be profitably carried on. A rainfall of less than 10 inches is insufficient for growing crops except by special methods or by the aid of irrigation. The heaviest recorded rainfall in the world is that in the region north of the bay of Bengal, where it has been known to reach 600 inches annually. The lowest record is that of the Mohave desert, in California, where less than 2 inches annually has fallen.

Storms. When the velocity of the wind increases to a mile or more per minute, it becomes a storm, rain or snow, and sometimes thunder and lightning accompanying it. A storm is usually the result of a disturbance of the atmosphere in some particular locality, but when once started it takes a direction fixed by the usual course of the winds in that place. **Cyclones** are whirling storms.

The whirl may be of all sizes, from the little dust whirlwind at the street corner to a storm that covers half a continent. To understand the beginning of a cyclone, let us suppose that in a certain locality the barometer is "low." This means that the air is light and rising. A low area usually has "high" areas surrounding it, perhaps at a distance of hundreds of miles. In "high" areas the air is heavy. The heavy air from the high areas soon begins to flow toward the low area. The air currents take on a spiral motion which grows swifter and swifter as they approach the center.

The movement of water flowing out at the bottom of a circular wash basin illustrates the formation of a spiral.

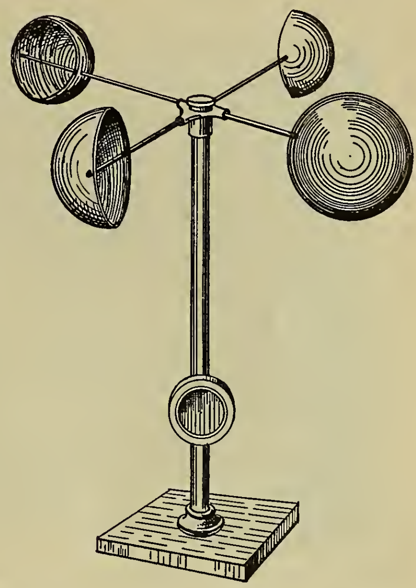


Fig. 96. The anemometer, an instrument for measuring the velocity of the wind.

The dry air flowing outward from the region of high pressure also moves in a spiral and is called the **anticyclone.** In the northern hemisphere the direction of the whirl is opposite to the movement of the hands of a clock, but this direction is reversed in the southern hemisphere. The air above the low area is warm and damp. When it rises into the cooler air above it the vapor is condensed, and rain follows. The rain will be heaviest at the storm center, as the center of the whirl is called. A very violent rainfall at the storm center is cometimes called a **cloud-**

burst. It is caused by the rapidly rising air currents, which hold the water suspended for a time, but afterward it comes down in sheets and continuous streams. Cyclonic storms have an onward motion, crossing the isobars into regions of low barometer. In the United States they cross the country from west to east, or from southwest to northeast, following the Atlantic coast. In the northwest, these storms are sometimes accompanied by fine, hard snow crystals, which cut like knives when driven by a high wind. Such a storm is called a **blizzard.**

Fig. 97. The movement of air currents from high to low pressure areas.

The weather maps on page 129 show the path of a low area from the northwest across the United States. Notice that the arrows showing the direction of the wind, cross the isobars at right angles, or nearly so, and move spirally about the low area. Fig. 96. Anticyclones follow the path of the cyclones. They bring clear weather, and take the name of cold or cool waves when they come from the northwest, and warm or hot waves when they come from the southwest.

A **Tornado** is a violent cyclone of small diameter. It is caused by a layer of warm, moist air breaking through an overlying stratum of cold air. The moist air rushes through the opening, taking the form of a huge, dark funnel which hangs from the clouds, small end downward. The rapid rise of the moist air causes the surrounding heavy air to rush into the path of the tornado with destructive violence. Everyone has noticed the rush of air into the wake of a swiftly moving train. It resembles some-

what the rush of air toward the tornado funnel, only while the train may be moving at the rate of 50 miles per hour, the velocity of the tornado is often six times as great. A tornado at sea draws up a column of water into its funnel, and is called a **waterspout.**

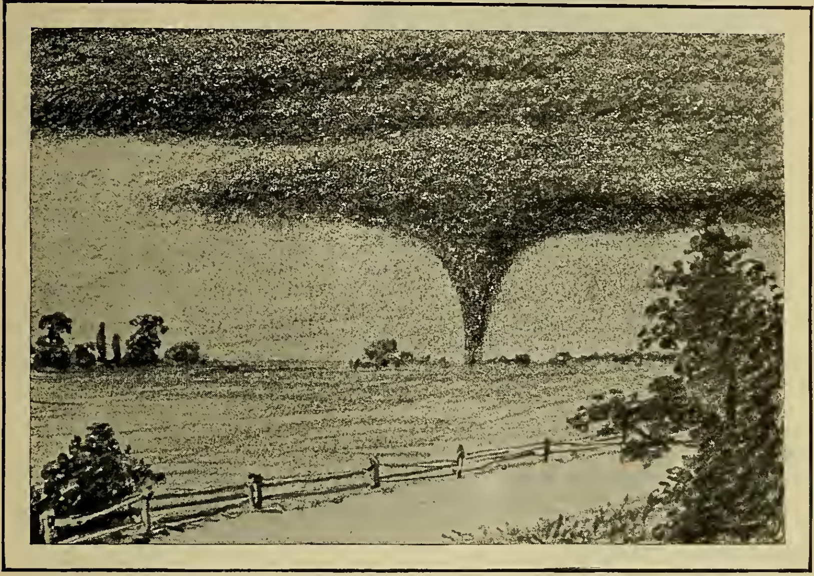


Fig. 98. A tornado on the great plains of the West.

Typhoon and **Hurricane** are names given to violent tropical cyclones in the Indian and Atlantic oceans, respectively. They are more severe than storms on land, as there are no irregularities of surface to check their course. When the West Indian hurricanes strike the coast a violent wave sometimes accompanies them. It was such a hurricane and wave that destroyed the city of Galveston in 1900. South of the equator these storms move southeast instead of northeast, as in the northern hemisphere.

Storm Charts. Sea captains avoid the storm center by taking a

course which carries them out of its path. By a study of the storm charts it appears that if you stand facing the wind, the storm center is on the right north of the equator, and on the left south of the equator. The ship, to escape the storm, must therefore sail with the wind on the right in the northern hemisphere and on the left in the southern.

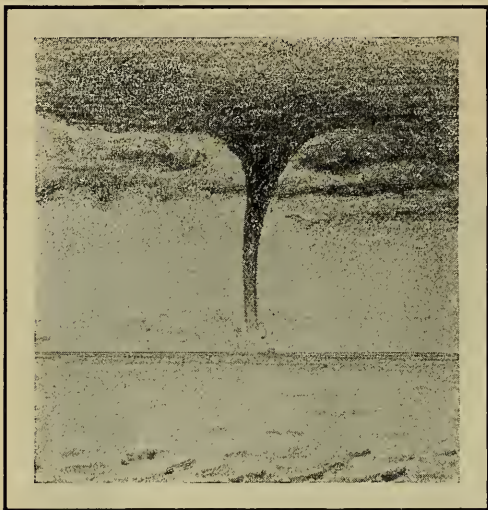


Fig. 99. A Waterspout.

Thunder-Storms. The most awful thunder and lightning usually accompany tornadoes and tropical cyclones. But local thunder-storms are frequent toward the close of hot, humid days in summer. The vapor expanded by the hot earth rises to the height of a mile or more and gathers in great cumulus

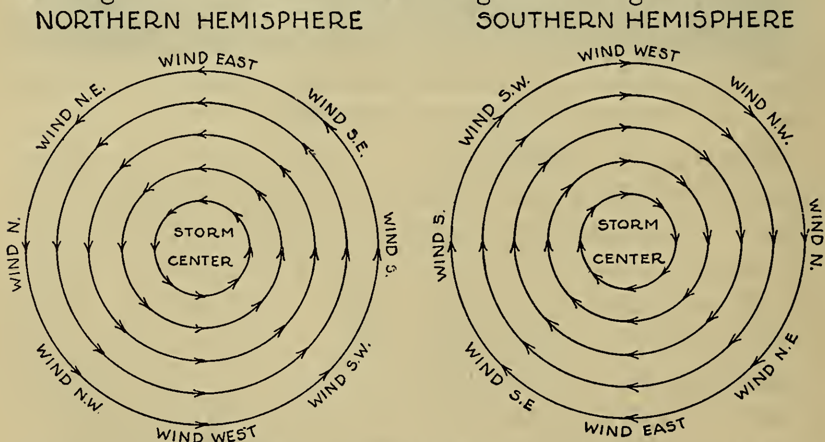


Fig. 100. Storm cards for the northern and southern hemispheres. To escape the storm center, the ship takes a course so that the wind blows from right to left in the nothern hemisphere and from left to right in the southern hemisphere.

clouds. After a time these condense into rain. The rapid condensation and the friction of moving masses of vapor cause electricity, or **lightning,** to flash from cloud to cloud, or from the clouds to the earth. As the center of the storm approaches, a column of cold air descends with the rain and spreads out at the bottom.

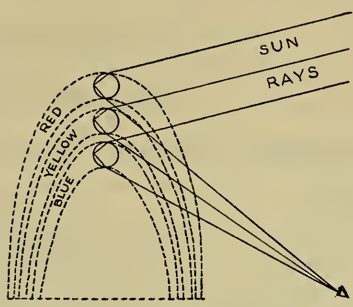


Fig. 101. Diagram showing the refraction of light by raindrops causing the rainbow.

The Rainbow. A thunderstorm passing eastward in the late afternoon is usually accompanied by a "rainbow." The raindrops falling from the rear of the eastward moving clouds catch the rays of the sun and turn, or refract, them backward. As each color has its own angle of refraction, it is seen in a different position from the other rays as shown in Fig. 101.

REVIEW. 1. What is the chief cause of atmospheric movements? 2. Give illustrations. 3. Describe the general circulation of the atmosphere upon the earth without regard to its rotation or the irregularity of its surface. 4. How is this system affected by the earth's rotation? 5. Name the three classes of winds. 6. How are the trade-winds caused? Where is the region of variable winds? 7. Describe the monsoons. 8. Land and sea breezes. 9. What is the cause of rainfall? 10. State the three principles governing it. Describe the tropical rain belt and its movements. Desert belts. 11. What is said of the rainfall of the temperate zone? 12. How is rainfall measured? 13. What is a storm? 14. What are cyclones? 15. What is said of their size? 16. Anticyclones. 17. Describe the rainfall during a cyclone. 18. What is a blizzard? 19. A tornado? 20. Typhoons and hurricanes. 21. Storm charts. 22. Describe a thunder-storm. 23. Give cause of rainbow.

CHAPTER XVIII

WEATHER AND CLIMATE

Difference between Weather and Climate. The pressure and temperature of the atmosphere with the resulting winds, rains, storms, and clouds are the elements that make both weather and climate. But weather is the state of the atmosphere with respect to these things at any given time, while climate is the **average weather** for a number of years. It is possible to have rainy weather in a dry climate or cold weather in a warm climate. We have cold winters and warm winters, wet seasons and dry seasons, in the same locality; but we find that the climate through long periods of time averages about the same.

Varieties of Climate. If the average annual temperature of a given locality is 60°, we call the climate **temperate.** If the annual range of temperature is high, say from 90° in summer to 0° in winter, the climate is called **extreme,** or continental. But if the range is low, we call it an equable or moderate climate. A **tropical** climate is marked by an average temperature of 70° to 80° with little variation in range. A dry climate with a moderate temperature is healthful; but a persistently hot and moist climate, or one subject to sudden changes, is unhealthful. There are so many elements determining climate that the climatic belts of the earth vary greatly from the zones and from the rain, wind, temperature and pressure belts. As none of the elements of climate con-

form with latitude, the climate of every well-defined natural division of the earth must be studied by itself in order to be understood.

Elevation is an important cause of the irregularities of climatic belts, since it affects both temperature and rainfall. The plateaus among the middle Andes mountains have

Fig. 102. Chart showing the average rainfall in the United States.

a temperate and healthful climate with moderate rainfall, while the lowlands of Brazil in the same latitude are hot, moist and often too unhealthful for human habitation. The drying effect of mountains upon the winds that pass over them has been mentioned (page 117). In some of the Swiss valleys and on the plains bordering the eastern slopes of the Rocky mountains, these winds, called "foehns" and "chinooks," evaporate even the snow and take the last drop of moisture from the soil. Dried by

passing the mountains and warmed by descending into the valleys, these winds are thus able to take up a large amount of moisture.

A uniform climate is most nearly approached in certain parts of the trade-wind belt and on coasts where winds are mainly from the ocean. Islands in the tropic seas like the Bermudas and the West Indies have an equable climate and a uniform rainfall. The western coasts of Europe and North America are in the region of westerly winds that are warmed by passing over ocean currents. The annual range of temperature is less than 20° and the air is uniformly damp and cloudy in winter and dry and clear in summer.

Climate and Weather in the United States. There are three broad climatic divisions in the United States. The Rocky mountains region has abundant rain in the north, where it is crossed by the westerly winds, but the southern half is almost a desert. The seasons are marked by extremes of heat and cold. This region is a good example of a continental climate. The lowland plains and the eastern coast of the United States, as shown on the map, are in the path of the cyclones and anticlones that traverse the country from west to east, and occasionally coming from the east and south. Cold, dry, and agreeable weather usually comes with the west winds in summer. This may continue for several days. Then the air becomes moist and warm; a thunder-storm breaks over the country, followed again by clearing and pleasant weather. In the spring, and especially in late summer and autumn, tropical storms of longer continuance sweep up the coast, bringing several days of rainy weather at a time. During the winter the storms are usually from the north

and east, while those from the south come very seldom, and when they do come bring rain and thaws.

Weather Forecasts. Careful observation for a series of years shows that the weather of any locality is repeated with slight variations year after year. About fifty years

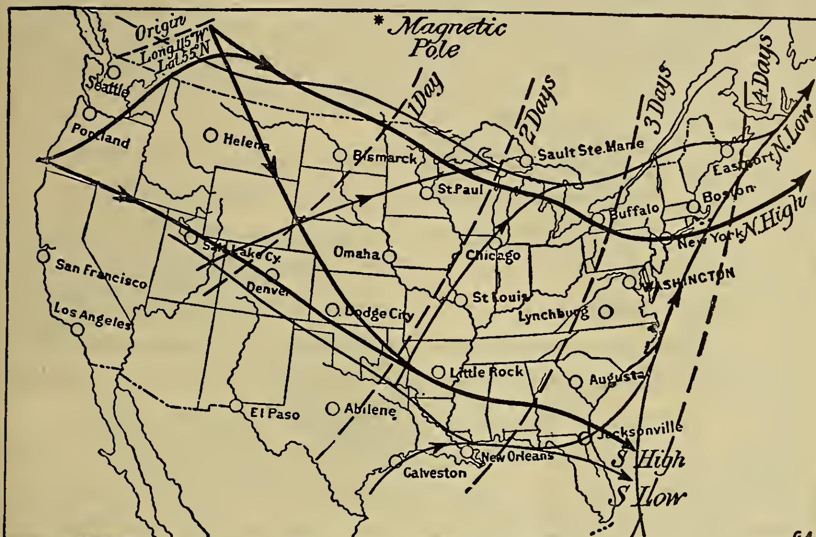


Fig. 103. Chart showing the usual path of storms in the United States. The heavy lines show the direction of storms, and the dash lines crossing them show the average daily progress of a storm center across the country, from west to east.

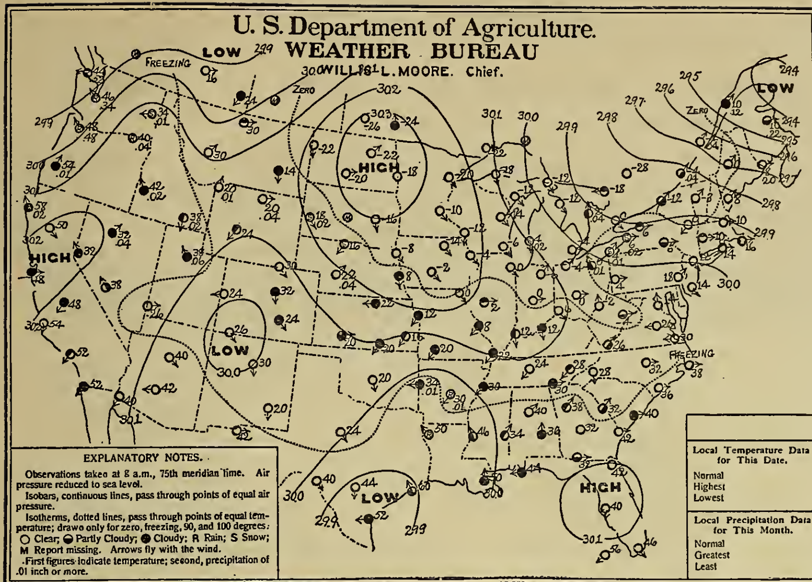
ago the signal service of the army began to record observations in regard to temperature, winds, and storms. Later the **Weather Bureau** was organized and signal stations were established in various parts of the country. At present there are about 85 of these stations, located in regions where weather phenomena can be best observed. A large number are along the Atlantic and Gulf coasts; some are in the valleys of the Ohio the Missouri, and the Mississippi rivers; about 25 are in the

mountain regions and on the Pacific coast; and others are along the Great Lakes.

Each morning at 8 o'clock, observations are made and telegraphed throughout the country. These observations include the barometer reading, temperature, direction and velocity of the wind, rainfall and the appearance of the sky. Having this information, the "forecast" officials can predict the weather for the next 24 to 30 hours. Storm signals are then displayed along the coast to warn mariners what storms or winds are coming and weather maps are made and may be sent to fruit-growers, farmers, and to all those whose business is in any way dependent on the weather.

Making a Weather Map. A map of the United States is printed, containing state boundaries, mountains, rivers, and plains, and the location of the signal stations. Each station is indicated by a circle. Through this an arrow is drawn representing the direction of the wind. If the circle is half blackened, the meaning is "partly cloudy"; if entirely blackened, "cloudy." Next, the temperature of each station is written, and isotherms are drawn connecting all stations having the same temperature. The pressure readings are next put in and examined to see which is the lowest. The station having this will be the center of the low-pressure area. This area is enclosed in a circle and the isobars are drawn.

The direction of the wind will be found to be nearly vertically across the isobars from high to low pressure. The succession of readings from high to low pressure is called gradient. The more the readings vary, the "steeper" the gradient and hence, the greater the velocity of the wind. The winds travel in a spiral movement toward the low centers and away from the high ones. The former are called "cyclones" and the latter "anti-cyclones." Cloud vapor is continually being forced by the cyclonic whirls into regions of low pressure, where,



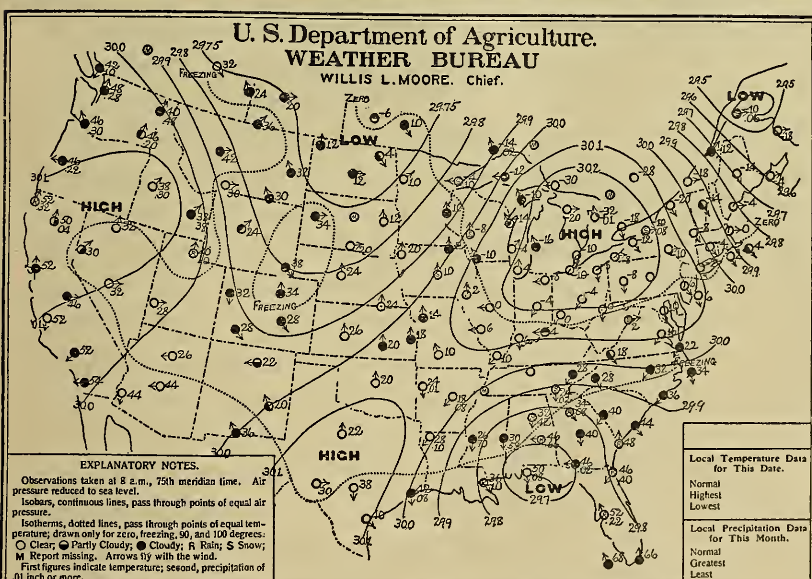


Fig. 104. Weather maps on two successive days in February, 1912. Notice the movement of the high and low pressure centers during twenty-four hours.

rising into the upper and cooler regions of the atmosphere, it is condensed to rain or snow.

REVIEW. 1. What are the elements of weather and climate? 2. How does climate differ from weather? 3. Name and describe some of the varieties of climate. 4. What is the effect of elevation on climate? 5. Give reasons why climate does not exactly correspond with latitude. 6. What is said of the drying effects of winds? 7. In what parts of the world is the climate most uniform? 8. Describe the climate of the Rocky mountain region of the United States. Of the region of central lowlands. 9. Describe the climate of the eastern coast of the United States. 10. Describe the work of the Weather Bureau. 11. How is a weather map made? 12. Meaning of symbols used.

CHAPTER XIX

PLANT LIFE

Organic and Inorganic Nature. The air, the sea, the soil, and the rocks belong to the **inorganic** kingdom. This means that in these things there is no distinction of parts. A rock may be broken in pieces and each is still a rock. But plants and animals belong to the **organic** kingdom. They are made up of various parts, or organs, each of which has a function; that is, something to do with the view to maintaining life and perpetuating its species. The root, the stem, and the leaf has each its own part in the growth of the plant, just as the heart, the lungs, and the stomach have their several functions in the life and growth of the animal.

Relation of Plant and Animal. One of these relations has been mentioned (page 99), but plants and animals are dependent upon each other in several other ways. Most animals depend directly upon plant life for food, though some wild animals, as the lion, the tiger, the wolf, and the fox, are strictly carnivorous (flesh-eating) animals. Again, animals die and their bodies mingle with the soil, thus furnishing valuable nutriment for plants. The erosion of limestone rock, which is made chiefly of animal remains, furnishes a rich soil. Plants depend upon the heat and light of the sun, moisture, the air, and the soil. The most important of these is heat. No matter how favorable other conditions may be, unless there is the proper temperature for a sufficient length of time, the

plant will not grow and ripen. If the temperature is below 32°, the freezing point of water, the roots cannot take moisture from the soil, the sap chills and does not circulate, and the plant dies. For this reason, the tops

Fig. 105. A tropical forest in the East Indies.

of mountains and the extreme polar regions are nearly destitute of plant life.

Zones of Plant Life. Each plant has a range of temperature in which it flourishes best. We may therefore divide the earth into plant zones according to temperature. Each of these zones has its characteristic forms of vegetation. These forms are not the same in all of the continents, owing to certain laws that govern the spread of plant life; but in size, luxuriance, and in number of species there is a regular gradation from the equator to the poles.

Soil and water are necessary to plant life. The leaves

absorb water, which keeps them fresh and straight. But it is in the soil that water is most essential. Here it dissolves minerals that are the proper food of the plant, and the rootlets absorb this moisture and carry it upward to nourish the plant, just as the blood circulates in the body of an animal and nourishes the several parts. As the blood of different species of animals varies, so each plant has its own peculiar sap. Besides furnishing mineral food for the plant, the soil gives to the roots a firm anchorage maintaining the stalk, or trunk, in an upright position.

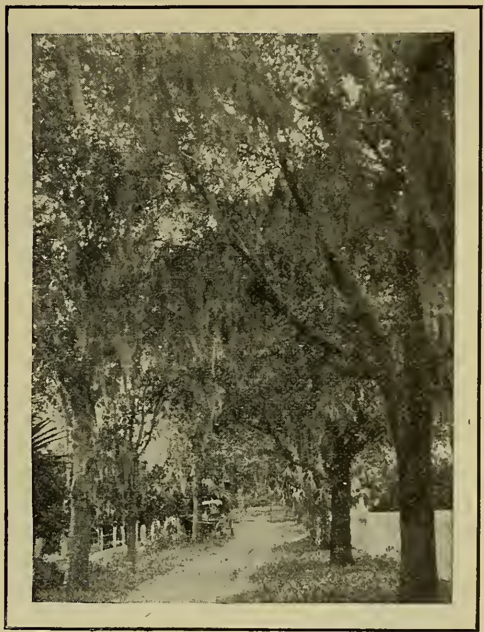


Fig. 106. An avenue of live oaks with Spanish moss in the southern states.

Light and Air. The air brings to the plant carbon dioxide (page 99), and the sunlight enables the leaves to absorb it and change it into sugar, cellulose, and other products which are peculiar to the plant. On the under side of every green leaf are very minute openings called *stomata* (mouths), through which the leaf breathes in the carbon dioxide. Each leaf contains a green material called *chlorophyl* (leaf-green), which has the power to break up the carbon dioxide into carbon and oxygen. The oxygen is given out again into the air,

but the carbon combines with water to form the several organic compounds named above. Without sunlight there would be no chlorophyl cells, and hence no plant growth. Thus the leaves are not only the *lungs* which breathe in the carbon dioxide, but they are chemical laboratories which manufacture from it the products which belong to the plant.

Fig. 107. A "buttressed" tree.

These products are as numerous as plants themselves, and are important to mankind as drugs, dyes, medicines, beverages, foods, and raw materials. Every part of the plant furnishes something useful. The root, the trunk, the sap, the seeds, the fruit, the buds, the leaves, the pith, and the seed-wings all make some contribution to the comfort, health, and convenience of man.

The Equatorial Belt is the region of the greatest variety and growth of plant life. Heat, light, and moisture are there in abundance throughout the year. Growth goes on without check by the cold of winter or the drought of summer. Trees of great height and of countless kinds abound in the forests. Dense undergrowth, trailing vines, and air-plants spring up among them, and, clinging to the trunks and branches, form a thick jungle below and an interlacing canopy above, which make an intricate tangle, dark and almost impassable. Palms in many and useful varieties, hard cabinet woods, and fruits and spices are abundant.

The Tropical Belts, with their hot summers and mild winters, lie next to the equatorial belt. Figs, dates, grapes, almonds, oranges, and lemons are characteristic fruits. Cotton, corn, rice, and sugar are the most valuable products. Pine, palmetto, cypress, and magnolia trees are the leading kinds. The redwood, the baobob, the eucalyptus, and the banyan trees are the largest.

Fig. 108. An avenue of royal palms.

The Temperate Belt is the home of deciduous trees, grains, and hardy fruits like the pear, apple, peach, cherry, plum, and quince. The oak, chestnut, ash, elm, maple, birch, beech, hickory, and numerous other species of trees are found. Plants known as herbaceous perennials are characteristic of this zone. The stalk and leaves of these plants die when the frost comes, but the roots live through the winter and send up a fresh growth in the spring. Others called annuals die altogether, and seeds must be sown every year to produce them. Numerous evergreens, as the cone-bearing trees, flourish in the cooler

Fig. 109. Gathering turpentine in a hard pine forest in the Southern states.

parts of this belt, especially in the uplands and mountain regions. The mountain tops afford only the lower forms of plant life. If we should ascend a mountain in Mexico or South America, we might find the same succession of plants that one might find in a journey from the equator to the poles.

The Cold Belt is the least productive of plant life. The long, cold winters and the deeply frozen ground kill all but the hardiest varieties. Pines, spruce, birches, and willows are found in the warmer parts of this belt, but there comes a limit, just as in ascending a mountain, beyond which no

Fig. 110. Palms along the Atlantic coast of Florida.

trees are found. Only mosses and lichens are found clinging to the rocks, and some water plants and mosses withstand the cold in the frozen swamps. In the short, hot summer of these arctic regions, hardy flowering plants, whose seeds have survived the cold, spring up and make the slopes and tundras bright with patches of green and bits of color. Flowering grasses, saxifrages and poppies are among them.

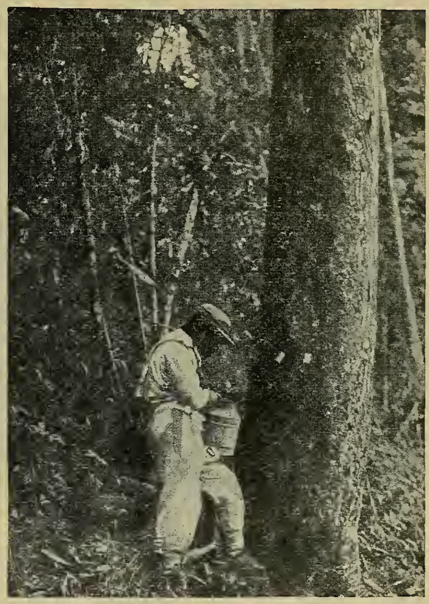


Fig. 111. Gathering rubber in the forests along the Amazon river.

Air, Water, and Desert Plants. Plants are found that are adapted to varied surroundings. Some, like the orchis family, are **air plants.** They fasten themselves to some support and their roots take nourishment from the air. Some are **parasites,** living upon other plants. The dodder and the mistletoe are of this sort. They take root upon the oak, willow, and other trees and take up the sap for their own support. Many weeds that live in the sea may be found washed ashore on any beach. Many kinds of lilies, rushes, reeds, and mosses grow in swamps, and in shallow lakes and ponds. Rice grows in marshes along the shore; the willow, cypress, and the mangrove live in

swamps. The victoria regia is a noted water plant of the Amazon. It has flat leaves with upturned edges, often several feet in diameter. Some plants are adapted to a very dry soil. The sagebrush and the cactus of the Southwest are such plants. They send roots deep into the soil, sometimes from 15 to 20 feet, in search of moisture.

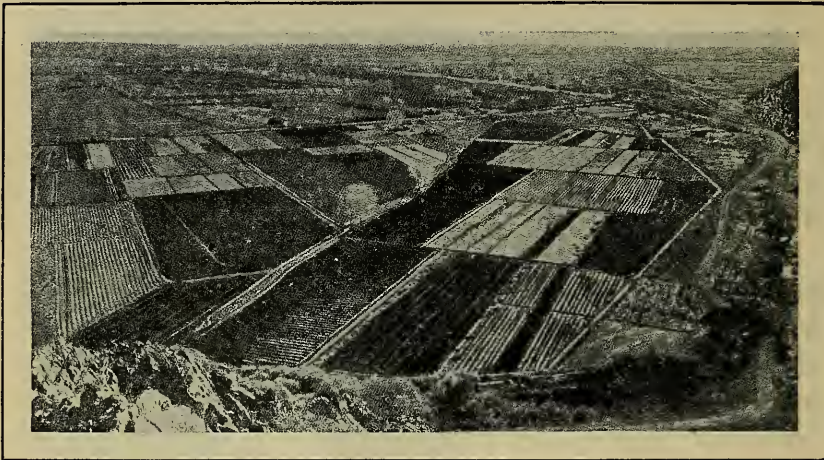


Fig. 112. Irrigated farms in Salt river valley, Arizona.

The Spread of Plants. Nature provides in various ways for the spread of plant life. Some seeds are winged, or covered with down or hairs and are transported by the wind. The thistle, dandelion, and maple are familiar. Other seeds are contained in elastic pods, which fly open, throwing the seed to a considerable distance. Beggar's lice, burdocks, and "stick-tights" cling to men and animals. Birds, rivers, and ocean currents carry them to new fields and strange shores. The vegetation of oceanic islands is due largely to the movement of ocean waters. Besides these agencies, civilized men have carried useful plants,

trees, flowers, fruits, and grains into every quarter of the habitable earth.

Broad oceans, mountains, deserts, dense forests, and currents flowing between and not toward shores may prevent the spread of plants. In such cases the flora (plant life) of two continents may be utterly different. The flora of Australia is unlike that of any other continent, and that of South America is different from that of North America and Europe.

Scientific methods of farming and gardening work great changes in the nature and value of plants. Cultivated fruits have little resemblance to their wild originals. One would hardly think that the jaqueminot and damask roses are descended from the humble wild rose that grows along the stone walls and in the neglected corners of the fields.

REVIEW. 1. Difference between organic and inorganic nature. 2. What is meant by an organ? 3. Describe the relation of plants and animals in regard to food. 4. Effect of temperature on vegetable growth. 5. Relation of soil and water to plant life. 6. Show how plants are dependent on light and air. 7. Describe the plants of the equatorial belt. 8. Plants of the tropical belts. 9. Plants of the temperate belts. 10. Plants of the cold belts. 11. Describe plants which are adapted to a dry climate. 12. Name plants adapted to a wet climate. 13. What are air plants and parasites? 14. How does nature provide for the spread of plants? 15. What are the chief barriers to the spread of plants? 16. How are plants affected by cultivation?

CHAPTER XX

ANIMAL LIFE

Animals and Plants Compared. Animals differ from plants in two important particulars. They have the power of moving from place to place, and are more independent of climate, since their bodies have the power of maintaining a certain temperature. They are unlike plants again in that they can do without sunlight and that their food is mainly vegetable or animal. But, like plants, they must have air and water.

Animals are adapted to their surroundings; their homes

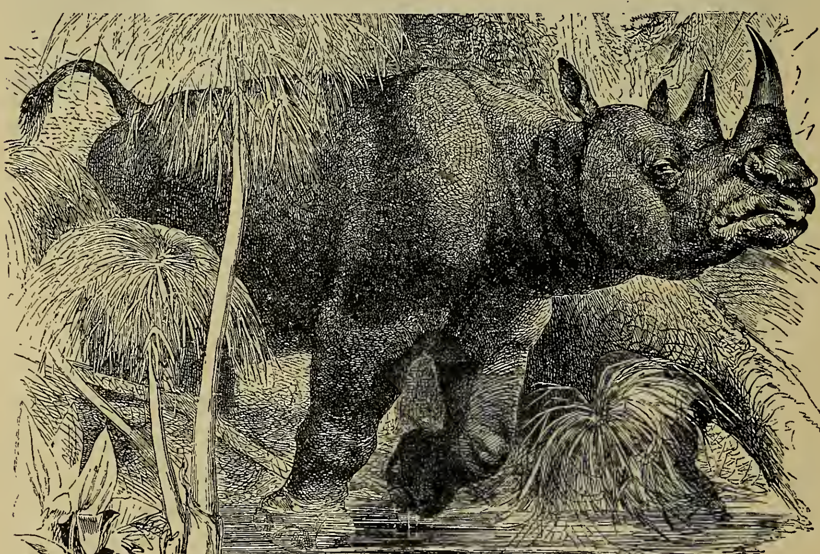


Fig. 113. Two-horned rhinoceros found in Africa.

are made near the places that supply them with food. The robin builds in the cherry tree; the crane and the stork live near ponds; and the tiger makes his home in the jungle, where he can stealthily pounce upon his prey. If by any means the proper food of an animal is destroyed it must find a new home or perish. Every animal is fitted by nature for securing its food, for defense against its enemies, and for preserving its young. The velvet feet of the cat and its sharp claws enable it to creep noiselessly upon its prey and to seize it. Unless the deer and the antelope were swift of foot they would soon be destroyed by their flesh-eating enemies. Every animal has its enemies, and life is a constant struggle for existence. The mole and rabbit burrow in the ground to escape their enemies, the weasel and the fox. But the weasel must himself avoid the fox, and the fox is in constant fear of the hounds. Birds build their nests in lofty trees to keep their eggs safe, or bury them in the earth or sand. Frogs lay their eggs in water, where the young tadpole may find

Fig. 114. The reindeer.

food; fish swim up the rivers and brooks and spawn upon the still, shallow places, where the eggs may be safe from swift water and the dash of waves.

Succession of Animal Life. The species of animals now living have not always been upon earth, nor are all

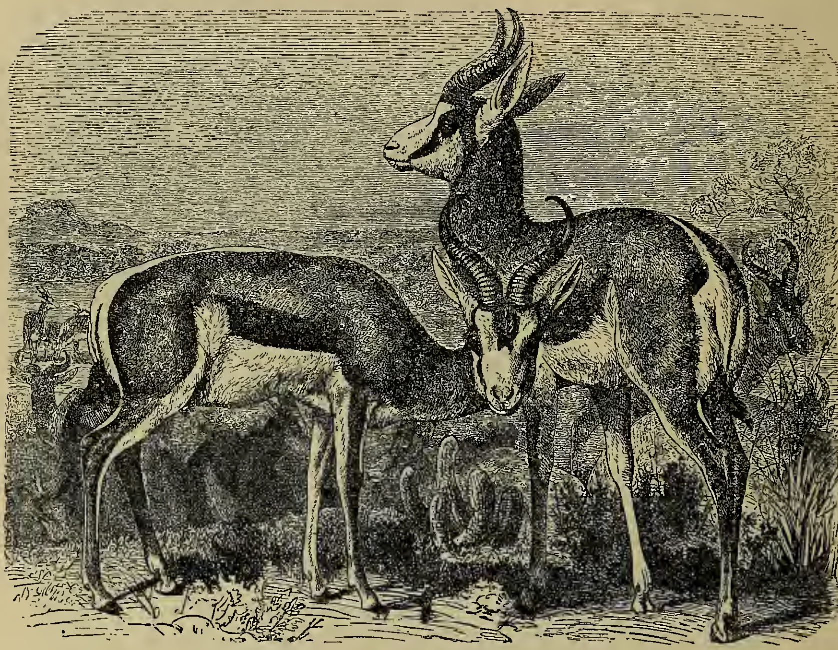


Fig. 115. The Springbok of Africa.

of them likely to remain. Countless forms of animal life are found imbedded in the rocky layers of the earth's crust, or buried in swamps beneath the ice of the Arctic regions. Bodies of a species of hairy elephant and rhinoceros have been dug up in Siberia. In the western part of Europe, huge species of elephants, deer, oxen, horses, bears, lions, tigers, and hyenas are found, all of which

are now extinct. In the United States are found the remains of huge lizards 20 to 30 feet in length, of birds with teeth, of the gigantic mastodon that stands 12 feet high, and of a thousand kinds of shellfish, insects, and lower forms of life. In recent times, the dodo and the duck-bill of the Australian region have become extinct, and the American bison is nearly so. Only strict laws have preserved the elephant, deer, moose, and many kinds of birds and fish that are sought by sportsmen.

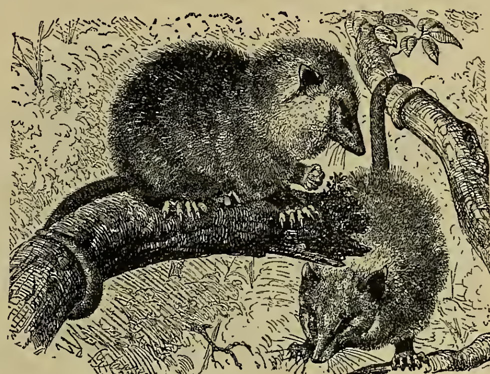


Fig. 116. Opossum.

Survival of the Fittest. Our present animals are only a few left out of the countless thousands that have lived upon the earth. By reason of their cunning, swiftness, strength, or ability to change their homes, they have survived the many changes in the climate and surface of the earth, and the attack of enemies. Animals with cumbersome bodies and without means of defense must give way to those of greater agility and fierceness.


Fig. 117. Wolf.

Distribution of Animals. Rivers, oceans, deserts, mountains, and forests are barriers

to the spread of animals, as they are of plants. Animals that can swim or fly can pass some of these boundaries. The swift sea-birds, the gulls, the pelicans, and petrels, pigeons, hawks, swallows, and cranes are found in every land. But in most cases, widely separated lands have different forms of animal life. The topography of the country, that is, its surface and elevation, somtimes explains the spread of animals, or their confinement to some particular region.

Fig. 118. Marten.

The chamois, sheep, wild goats, and the South American llama and alpaca are fitted only for mountain life, and could not live elsewhere. The hippopotamus and the alligator live on the banks of rivers for the same reason that the reindeer and polar bear live in the Arctic regions, because their bodies are adapted to such surroundings. Each animal is limited to a certain *habitat*, or range, as well as by natural barriers. Its habitat is the area within which it may find not only food and safety, but which is also best adapted to its habits of life. The domestic animals have been carried by men into every land. The horse, the cow, the sheep, pig, goat, dog, and cat seem to flourish in as great a variety of climate as man himself, if only food and shelter are provided for them. The animals that are not cared for in this way are confined to narrower bounds.

The Realms and Regions of Animal Life. We may divide the earth into three temperature zones of animal

life, the Arctic, the Temperate and the Tropical. The Arctic realm abounds in birds, fur-bearing animals, deer, sea-animals, and fish. The polar-bear, seal, and walrus live upon the ice. The caribou, the musk ox, and reindeer live on the Arctic plains and feed on the scanty vegetation

Fig. 119. Kangaroo.

which they afford. Some of these animals are migratory and seek homes farther south when the snows of winter, cover their food. Most Arctic animals are white or dull in color and are provided with thick fur, hair, or feathers to protect them from cold.

The Temperate Realm may be divided into North America, Eurasian, and Australian regions. It is known that many species of animals in the northern temperate regions were destroyed by the cold of the glacial period. Several species of bears are still found, of which the grizzly is the

largest and fiercest. Of the great herds of bison that once roamed over the western plains, but only a few are now left. Mountain lions and big-horn sheep are found in the Rocky mountains, and many valuable fur-bearing animals, as the otter, mink, beaver, lynx, ermine, sable, and fox are

Fig. 120. The Bactrian camel.

found in the Hudson Bay region. Horses, cattle, deer, and antelope are native to the central plain.

The Eurasian Realm includes Europe, northern Asia, and northern Africa. Among beasts of burden are the yak, camel, dromedary, the wild horse, and ass. The yak is found only on the high plateaus. It is domesticated as well as wild, and supplies milk, meat, and valuable

skins as well as useful labor. The chamois is another peculiar mountain animals; it is found among the rocky heights of the Alps. Many birds and animals are common to the whole northern realm of America, Europe and Asia. Crows, finches, grouse, jays, pheasants, bears, deer, antelope, wolves, frogs, mice, moles, rats, and countless other varieties are found only in the northern region.

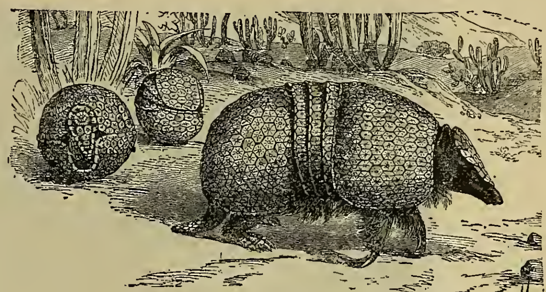


Fig. 121. Armadillo.

The Australian Realm is the most remarkable of all the plant and vegetable regions. It is difficult to find there any forms that occur in the other continents. The Australian realm includes also New Zealand, New Guinea, Tasmania and the neighboring islands. The marsupials, or pouched animals, are found here; they have a fold in the skin on the under side of the body, in which the young are carried while helpless. These animals progress by hopping on their hind legs, aided by a long muscular tail. The kangaroo is the leading species of them. The emu and cassowary are birds without wings; they have hair instead of feathers and can run very fast. The lyre-bird, the cocatoo, the kiwi, the parrots, and the apteryx of New Zealand are entirely unlike any other birds. Many animals like those of the Australian kingdom are found in the rock layers of Eurasia; but the only living specimen that resembles them is the opossum of the United States. It is believed that Australia was once connected with the

mainland of Eurasia, and that these animals were common to both regions; but the larger and fiercer Eurasian animals lived at that time far to the north and did not find their way to the Australian region. Afterward, by a sinking of the land, a deep-sea passage was formed between the two continents. Being thus cut off from the fierce enemies

Fig. 122. The sloth.

that destroyed their Eurasian relatives, the peculiar animals of Australia have lived in peace down to the present to show us some of the strange creatures that were once widely spread over other lands.

The South American Realm has some animals quite as strange as those of Australia. The condor, the largest bird of flight, lives among the Andes, The rhea, or American ostrich, is found upon the plains, the grass of which it resembles in color. South America is the home of bright-colored birds. Parrots, tanagers, the toucan, the umbrella-bird, and almost 400 species of hummingbirds are found. They are red, yellow, bright green, orange—as bright in

color as the flowers among which they flit. Monkeys, serpents, and insects are quite as plentiful as birds. The shields of bright-colored beetles and the feathers of birds are used by the Indian in making ornamental work remarkable for beauty. The jaguar, a kind of panther, is the only dangerous wild animal. It prowls about at night, and

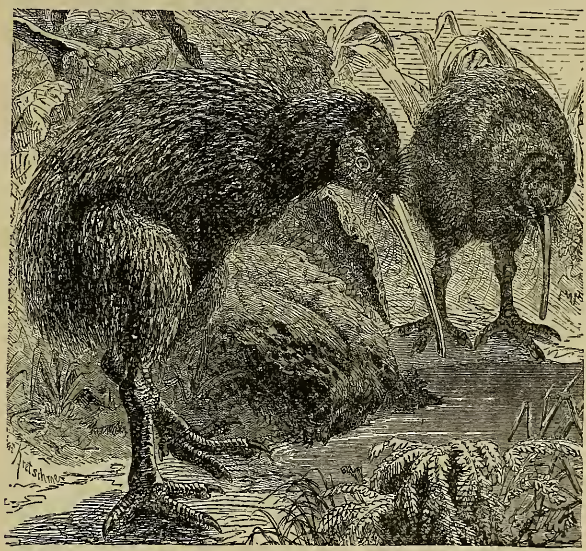


Fig. 123. The apterix.

sometimes enters the cabins of natives. The llama, alpaca, vicuna, chinchilla, and the guanaco are animals of the camel family, but are very much smaller. Their fine hair is valuable for making cloth. South America affords splendid pastures for horses, cattle, and sheep, but none is native to the country, having all been taken there by settlers.

The African Realm is the most famous for animals of great size, fierceness, and strength. The elephant, leop-

ard, lion, rhinoceros, hippopotamus, gorilla, and wild boar are most familiar. The hyena, quagga, the horned gnu, many species of deer, as the eland, giraffe and antelope also abound. The chimpanzee is the animal that most resembles man. The most famous bird is the ostrich,

Fig. 124. The emu.

which is hunted and domesticated for its beautiful feathers. A curious insect is the tsetse fly, which lives within a limited area, and whose sting is fatal to cattle, horses, and dogs, but does not injure man.

The Oriental Realm includes southern Asia and the East India islands. The elephant, the zebra, and the water buffalo are the most useful animals found in this region, and are trained to do all manner of work. The rhinoceros, tiger, and lion are also found. The animals are most like those of Africa. The man-like apes, the

orang, and the gibbon resemble the chimpanzee and the gorilla. Poisonous serpents are common. The Indian cobra is the most dangerous of these. Huge crocodiles are found in the Ganges delta and are useful to man in

Fig. 125. The sun bear of the Oriental realm.

consuming the carrion that floats down stream. The fauna (animal life) of the islands resembles that of the continent except that none of the larger and fiercer animals are found.

The ocean everywhere teems with life. Its shallow


Fig. 126. The orang.

waters are filled with many varieties of fish, whose names are well-known to all on account of their value as food. Many sea-animals resemble plants in lacking the power of locomotion. Sponges, polyps, barnacles, and sea anemones are fixed to the rocks. Others, as the crabs and lobsters, crawl upon the bottom. The seal and walrus have been mentioned as being partly land animals. They with the whale and dolphin are mammals, and suckle their young. Curious animals have been brought up from the ocean bottom by dredging. Some of these are blind. Others give out a phosphorescentlight, resembling in

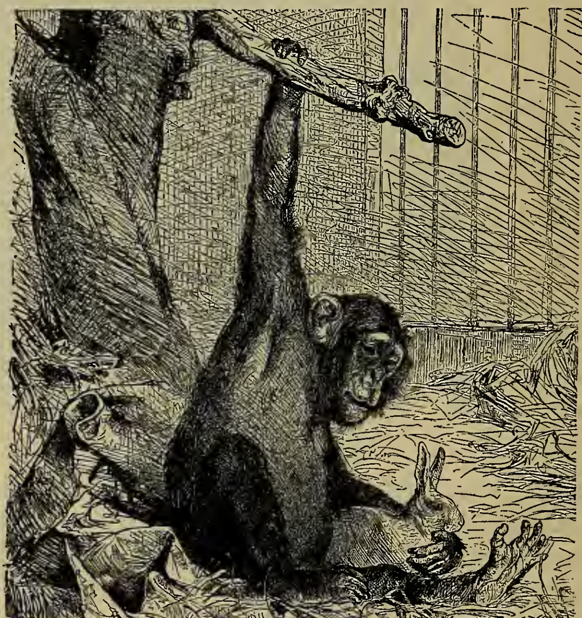


Fig. 127. The chimpanzee.

this particular certain minute forms that float on the surface of the ocean and emit a faint glow. The animals found in the greatest abundance and variety are shellfish. They take the lime from the water and build up their shells. Their shells are washed upon the shore or sink to the bottom

Fig. 128. Forms of marine life. At the top are corals with polyps, a sword-fish and jelly-fish. Several curious fishes found in tropical seas are in the center. At the bottom, are sea anemones and a star-fish.

in shallow waters. Such lime deposits, when raised up into hills and mountains, form a large part of the rocks of the earth's crust (page 36).

REVIEW. 1. Differences between plants and animals. 2. Show how animals are adapted to their surroundings. 3. How are animals fitted for obtaining food? How for defense? 4. What is said of extinct animal life? 5. Name animals which have recently become extinct or are in danger of becoming so. 6. What is meant by "survival of the fittest"? 7. Explain why some animals are more widely distributed than others. 8. Name the three zones of animal life. 9. What are the three divisions of the temperate realm? 10. Name the characteristic animals of Eurasia; of North America; of Australia. 11. Describe the animals of the South American realm. 12. Animals of the African realm. 13. Animals of the Oriental realm. 14. Describe the animal life of the ocean.

CHAPTER XXI

MAN

Origin of Man. How and where man first appeared upon the earth we do not know. As to *when* he appeared, we can only say that there is good proof that he was on the earth at the time of the glacial period, and that this was many thousands of years ago. He did not appear until the earth was fitted to support human life. In the earliest period of the earth's history there was only dead matter. But when the waters cooled, plant and animal life appeared in the sea; and when the land rose above the waters and soil formed, it appeared also upon the land. At first only the lowest forms of life are found—seaweeds, lichens, and mosses among plants, and shell-fish, polyps, worms, and articulates among animals. But as ages passed, the forms of plants and animals became more elaborate. Fishes, reptiles, mammals, and man appear in a constantly ascending series.

Evolution. In the case of plants and the lower animals it is clear that higher forms come as the result of improved environment, or surroundings. These consist of better air, light, and food. If we cultivate a wild plant, or tame a wild animal, we obtain after a few generations better varieties and breeds. This obtaining of higher forms out of lower ones is called **evolution** or **development.**

Some people believe also that man is a development from lower forms of animal life, such as the ape, the gorilla, or the monkey. This theory, however, is not proved.

All the knowledge we have concerning these matters is obtained from the study of the fossils, or remains of living things found in rocks. No living or dead species of animals have yet been found which resemble man closely enough to make us believe that he is descended from

Fig. 129. Homes in New Guinea.

them. There is too great a difference in the shape and capacity of the skull to permit the belief that one descended from the others.

The great and distinguishing feature of man is the possession of language, or articulate speech, while animals have only a cry, a continuous sound. Man also has reason, which is power to distinguish right and wrong, true and false, good and evil. This power no animal possesses.

Civilization. But the quality that makes the greater

gulf between man and the animals is his capacity for improvement. It is true that some tribes and nations remain stationary in the savage or partly civilized state. But it is also true that they show the ability to improve their condition when the way is pointed out to them. It is beyond doubt that in his original condition man was a savage. He lived in a thicket or a cave; he was unclothed, and his food was the fruit of the earth and such animals as he could kill with his hands. The use of fire and the making of knives, axes, and spear-heads from stone were among his earliest inventions. The invention of the bow and the making of pottery were the next great steps in advance. The game that he killed with his arrow supplied food, clothing and shelter. The vessels of clay could be used for cooking and storing his food and drink. The discovery of fire led to the working of metals and to improvement in the weapons and implements that man used. The taming of the cow, sheep, goat, horse, and camel was the next advance. Man became a shepherd and herdsman. At about the same time the cultivation of food-plants was begun. Fruits and grains are still the chief food of mankind.

Fig. 130. Native Indian of Central America.

Commerce is man's natural impulse; trade began as

Fig. 131. Civilized life — country.

Fig. 132. Civilized life — city.

soon as a man had acquired something that he did not need and had found another man with something that he did need. Trade promotes industry, and is a great civilizing agent. Men learn from each other; the need of keeping accounts led to a system of writing. The Phenicians, the great commercial nation of ancient time, invented the alaphabet and carried it to every part of the known world. Manufacturing is encouraged by trade. Men make those things which they need for themselves and also the things which they can sell to others. Trade and manufacturing led to the discovery of new lands and the planting of colonies. New supplies of raw material must be found and new markets for the manufactured products.


Fig. 133. Chinese official.

Stages of Progress. On the basis of occupation we may divide mankind into five classes: hunters, herdsman, farmers, manufacturers, and merchants. We may also divide them according to the materials and forces employed. Thus we have the age of stone, the age of bronze, the age of iron, and the age of steel. We also speak of the age of steam and the age of electricity. All these stages indicate the gradual civilization of man.

Distribution of Man. Every part of the world that supplies food and sufficient protection from the elements is inhabited by man. And the earliest mention we have of any land shows that it was then an inhabited land. Wherever explorers and colonists have gone, some earlier race is found in possession of the soil. The reason for this wide distribution of man is that he is able to overcome the disadvantages of climate. His intelligence enables him to protect himself from heat, storm, and cold, and to obtain food in ways impossible to the lower animals. It has also enabled him to cross wide oceans and thus to pass from continent to continent and from island to island until all parts of the habitable have become populated by the several races.

Fig. 134. Natives of New Guinea.

Influence of Climate and Surface. The state of civilization and the occupations of men depend largely upon their surroundings. The Eskimos can obtain food and shelter sufficient to keep them alive; but the effort to do this takes all their time and strength. Among mountain regions, too, it is often so difficult to get a living that there is no energy left for progress. In the very hot regions of the

earth, great exertion is neither necessary nor possible. Men can live on the natural products of the earth, and clothing and shelter are scarcely needed.

Inland regions are not favorable to civilization, unless there is means of intercourse with other people. People

Fig. 135. A Blackfoot Indian chief. (After Catlin.)

living remote from the sea coast and having little communication with the world soon get behind the times in language and customs. They do not invent new ways of doing things, and they stagnate in both intelligence and energy. The best condition for civilization is a land where food is abundant and climate temperate, and where

there is good means of communication and an extensive sea coast.

Races of Mankind. There are several ways of classifying man, none of which is entirely satisfactory. Men are found of all shades of color from white to black, and of all degrees of civilization. Different surroundings after long periods of time produce different races. It is believed that all mankind are descended from one pair and that the varied races of the earth are the result of physical surroundings and different modes of life. How long a time must have elapsed, then, between the creation of our first parents and the present!

Fig. 136. Hindoos.

Fig. 137. Caucasian race of Western Asia.

Each nation develops a slight variation in race. The English, Dutch, and Germans are of the same race, and once lived on the same soil. But it is easy now to distinguish them.

According to color features, we may divide mankind into four distinct races: the white, yellow, red, and black. Woolly hair, thick lips, flat nose, black eyes, and low civilization characterize the black races of Africa and the islands of the Pacific ocean. The Mongolian, or yellow, races have a color ranging from yellow to brown, small, black eyes obliquely set, and straight, black hair. In civilization they range from the highest to the lowest. The American, or red, race is marked by straight, black hair, straight nose, black eyes, and low rank in civilization. The Caucasian is the highest type of mankind. In complexion and in color of hair and eyes the members of this race vary. Their features are regular, with straight nose, thin lips, and wavy and abundant hair and beard. They rank highest in civilization, and are especially noted for their inventive genius, manufacturing skill and attainments in the fine arts and literature.

Fig. 138. A Manchu lady.

The white races are noted for the control they have

obtained over the resources of the earth by improved methods in agriculture, mining, natural power, and transportation. Steam, water power, and electricity are utilized according as economy or commerce dictates. Enterprise, wealth, and steamship navigation have carried them into every part of the globe, while the other races have remained stationary or have declined in power.

Fig. 139. Arabs at prayer.

REVIEW. 1. What is said of the origin of man? 2. Tell something about the succession of life which has appeared upon the earth. 3. What is meant by evolution? 4. What objection is there to the theory that man has been evolved from lower animal forms? 5. Name the several stages of progress or civilization characteristic of man. 6. Distribution of man. 7. How is civilization affected by surface and climate? 8. What are the three leading races of mankind?

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